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A . Report Title: A SAMPLE OF EUROPEAN RESEACH ON FUZZY LOGIC.

B. DATE Report Downloaded From the Internet: 6 AUG 98

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #): DEPARTMENT OF ELECTRICAL &COMPUTER , ENG & COMPUTER SCIENCE UNIVERSITY OF CINCINNATI , MAIL OCATION 0008 CINCINNATI,OHIO 45221 (513)556-4752

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by: DTIC-OCA, Initials: __LL__ Preparation Date 06 AUG 98

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A Sample of European Research on Fuzzy Logic

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Foreword

The idea to write this report came while discussing about fuzzy logic related work in Japan with David Kahaner, Director of the Asian technology Information Program in Tokyo. Having both spent a number of years there (at the time I write this David is still in Japan) we had the opportunity to follow the rise of this field there, to heights never imagined by those involved in it, and dreamed by every single scientist or engineer.

During the last two or three years, rumors from Europe reached Japan as well indicating that a similar phenomenon was starting there too. In particular in Germany, industry and a number of academic laboratories have vigorously pursued work in fuzzy systems, especially fuzzy control, their most successful branch. At the same time the number of meetings dedicated to fuzzy logic has increased dramatically. All these events suggested that a report covering some of the work done in Europe in this direction would be desirable.

It appears that the current state of affairs was very much triggered by the news on fuzzy logic incorporating products coming out of Japan, and that it may, in a way constitute a response to repeated warnings that Europe will be left behind by the Japanese industry. For example, we read in the March 19 1990 issue of the French Les Echos - Industry Section - the conclusion of a panel of experts assessing the effects of fuzzy logic development in Japan. *"...Either enough people and organisms realize in France and Europe the interest and maturity of the methods based on fuzzy logic and theory of possibility and obtain the conclusions which will allow the industry to conquer at least a portion of the future market, or the Japanese will end up obtaining from the international research community that which they might be still missing to dominate definitely and totally all the field of applications"*[1]. Implied in this warning is the old and, to my view naive opinion, that the Japanese lack creativity. I will not debate this issue here. However, whatever the case might be in any other field I am convinced, after having worked among and with Japanese researchers for four and half years, that in the field of fuzzy logic and its applications they have given proof of extreme creativity.

Gone was the inclination to view this Japanese preoccupation with things fuzzy as a peculiar cultural characteristic. Suddenly this became a technology which sold well and it was necessary that Europe should catch up. Thus, new conferences were organized, new programs, national and European were created, as well as task force groups were formed to investigate, to advance and become competitive in this field. I have tried in this report to convey to some extent some of the work being done at various

[1]This is my translation of the original French text.

sites in Europe. Given the time allocated for this I have managed to cover but a small part of what is going on. However, I trust that this will give some idea about the activity in this field.

Table of Contents

1. Introduction

The year 1995 marks the thirtieth anniversary of the first paper on fuzzy sets. In the intervening years fuzzy sets, fuzzy logic and associated techniques have seen a steady development, both at theoretical as well as at practical level. Leading the practical applications to commercial systems were Asian countries (first Japan, starting around the mid eighties and more recently Korea). The recent experience with fuzzy logic based systems has shown that these cut across many areas of engineering and scientific research: mathematics, systems engineering, artificial intelligence, cognitive science and psychology, etc. In addition to providing a new tool for problem statement and solving, a unique feature of fuzzy logic is the ability to be incorporated, **as needed**, in classical approaches, in order to eliminate, or alleviate deficiencies.

To understand why a report on fuzzy logic might be helpful let us throw a glance at some historical data concerning the field of fuzzy logic and its development in various parts of the world.

The notion of a fuzzy set has been introduced in 1965 by L. A. Zadeh[2], a professor at University of California, Berkeley. In an informal way we describe here the main idea behind this concept: by analogy with the classical set theory, where a set is identified by its indicator function, defined on a universe of discourse (e.g., the real numbers, R) and taking two values only, 1 or 0, corresponding to whether a point is in the set or not, the fuzzy set is identified by a *membership function* , defined on the same universe but taking values in the **interval** [0, 1]. Evaluated at a point in the universe of discourse the membership function is the degree to which that point belongs to the set under consideration. As a very simple example we can have the notion of "numbers much larger than 100". In this case one can see that while for some numbers we can say definitely that they are/are not in the set for, others the property is verified to some degree only (e.g. the degree to which 101 is much greater than 100 would 0; the degree for 10,000 would be greater than that for 5,000, etc.). This fuzzy set might have a membership function as shown in Fig. 1.1.

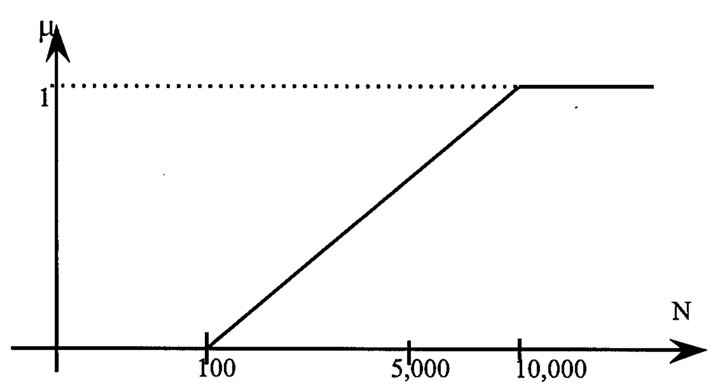

Fig. 1.1 Example of a fuzzy set membership function for the fuzzy set "numbers much greater then 100"

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[2]Zadeh's first paper (Fuzzy Sets) appeared in Information and Control No. 8, 1965.

Note that the shape and parameters of the fuzzy set are not unique - they can be determined from data or they can be given by the designer.

Well-known for his work in systems theory, Zadeh has invented this new concept (which in spite of its rather modest extension of the classical concept has a significant impact), from a need to characterize a system, in a way which is at the same time meaningful and with adequate precision. To illustrate the dichotomy between meaning and precision and the necessity of fuzzy logic, we quote here Zadeh's Principle of Incompatibility (1973) and Terano's principle of humanity in engineering (1994).

Principle of incompatibility (Zadeh 1973): As the complexity of a system increases the ability to describe it exactly and meaningfully decreases - thus high complexity and exact and meaningful descriptions are incompatible.

Principle of humanity in engineering (Terano 1994): The extent to which fuzzy engineering is necessary depends on the extent to which the designer accounts for the human user - thus the more human the system the more fuzzy logic is needed.

Since its inception fuzzy logic has been surrounded by fierce controversy and debates. Indeed it can be argued that it is perhaps the most debated of the new fields of research. Mainly, the controversy arises in two directions: fuzzy logic as a model of uncertainty; fuzzy logic as a system of reasoning.

From the point of view of the first fuzzy logic is viewed as challenging the role of probability and statistics. With respect to the latter fuzzy logic is seen as an inadequate system of logic unable, for example, to support long chains of reasoning, etc.

In trying to elucidate the first point, and to convey informally the fact that fuzzy logic and the probability model are complementary rather than competitive let us consider the following example: Let us suppose that we consider the task of recognizing an object in an image. Suppose that we have several images of the object, in some the object is completely visible in others the object is gradually occluded. Suppose that in each case we can calculate the extent to which the object is in the image based on the visible area and the total area of the object (as might be estimated from the visible area). Let us consider now two types of objects - man-made objects, such as a box and natural objects such as a bush/tree.

It is clear that in the case of the box we can say that this is in the image with a degree of certainty based on the ratio of the areas described above. Thus, when the box is not occluded the box is in the image with degree 1. Things are not as obvious for the bush/tree example: the difficulty to distinguish exactly between these two natural concepts will be reflected by the fact that even when the object is totally visible we may not be able to recognize the object to degree equal to 1. Moreover, partial occlusion of the object adds to the uncertainty of recognition.

We deal in this two examples with two types of uncertainty :

o uncertainty due to **lack of data** (the box example): In this case when all the data is available there is no uncertainty associated with the recognition, since the box has a very exact definition which can be retrieved/verified in its entirety.

o uncertainty due to **lack of definition** (the bush example): In this case even when we have all the data there will be a degree associated to the recognition, since there is no exact, unique definition for the concept bush (to distinguish it from that of tree for example).

The above example illustrates at the same time the complementarity between fuzzy logic and probability: in the case of the bush example we can easily distinguish the two types of uncertainty.

In the debate surrounding fuzzy logic a frequent argument against fuzzy logic points to the fact that while there is strong support in nature (from quantum mechanics) for randomness (which then gives rise to the use of probability) there is no such support from natural phenomena for fuzzy logic.

Against this argument I offer the following quote from a distinguished scientist[3] (italics added): "...I have left to the end the third of the three ways in which human being may differ from one another, because I shall discuss it a greater length my next two lectures. *Most characteristics do not divide us into sharply distinct classes of the sort I have been discussion so far. Our heights, or wits, or over normal range of variation our blood-pressures form a smoothly graded series; tallness or shortness, brightness or dullness, are simply stretches of a continuous range.* The inheritance differences of this kind behaves as if it were due to the cooperation and interaction of a very large number of genes; and the same goes for the characteristics which do divide us into distinct classes, like the number of children one can have....Unhappily, the study of this form of inheritance, 'metrical' inheritance is exceptionally difficult both in theory and practice".

[3]Peter Medawar, The Future of man (BBC Reith Lectures 1959) The Threat and the Glory - Reflections on Science and Scientists Oxford University press 1990. Sir Peter Medawar was a Noble Prize winner for work on tissue transplant and has written and lectured extensively on various aspects of Science and scientific research, including on some AI projects, drawing mostly negative conclusions about their performance.

2. Fuzzy Logic Control for Industrial Applications at FLS Automation, Denmark

General Information

FLS Automation A/S is a Danish company in the F. L. Smidth Group (Figure 2.1, Table 2.1) which is the largest industrial group in Denmark employing more than 16,000 people. FLS Automation headquarters are in Valby, a suburb of Copenhagen.

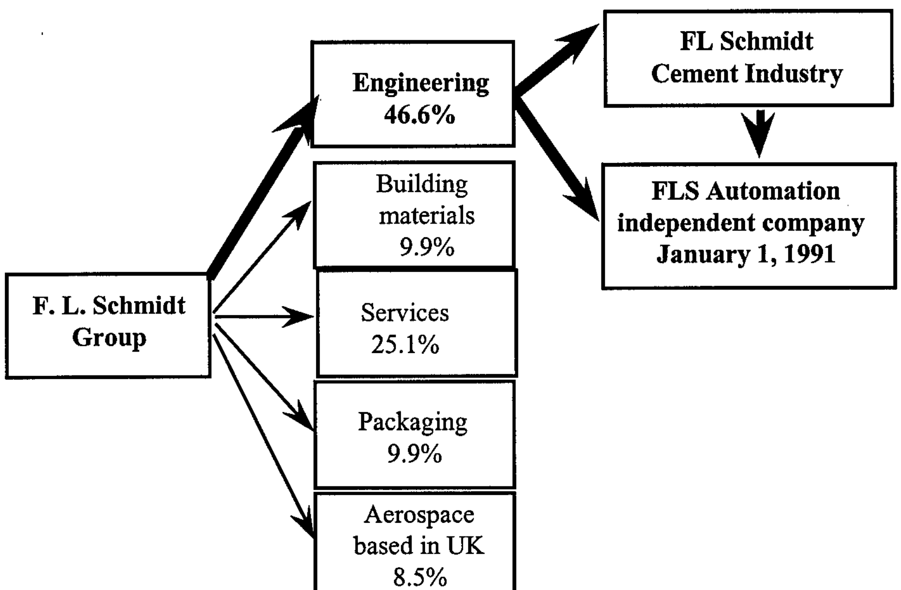

Fig. 2.1 Diagram showing the relation of FLS Automation with the FLS Group

Table 2.1: FLS Automation profile: sites and personnel

Technical staff in Denmark:	
Copenhagen	162
Mariager	15
Aabenraa	18
Business representatives abroad:	
USA (Baltimore)	
Spain (Madrid)	
France (Paris)	
Japan (Tokyo)	
etc.	

The primary activity of FLS Automation concerns the cement industry (Table 2.2): producing systems for measuring, controlling and regulating complex industrial processes; its equipment is supplied to cement plants worldwide.

Based on the concept of Adaptive Control Engineering (ACE) FLS Automation plans and implements projects from the concept stage to the commissioning of the system. FLS Automation is not dependent on any particular hardware supplier.

With a strong commitment to research and development FLS Automation pioneered a number of new techniques:

- o development of computer based process control;
- o first industrial application of fuzzy logic control in the framework of an expert system for cement kiln control;
- o first to market computer-based temperature scanners for rotary kilns;
- o first to introduce large robots in laboratory automation.

Table 2.3 summarizes the type of systems, and corresponding applications produced by FLS. The evolution of QCX products at FLS Automation is shown in Table 2.4.

Fuzzy II Control System

Fuzzy II is a general Tool Box for high level process control comprising a well defined and modular structure for implementation of control objectives. The control objectives are assigned priorities and the Priority Management System of Fuzzy II ensures that objectives are fulfilled in order of importance

The Fuzzy II High level Control System is an application module on the FLS--SDR platform.

Main features of SDR include:

- o process signal communication
- o plant reporting functions
- o graphical; trend curves
- o process mimic diagrams

The Fuzzy II control strategy is implemented as follows: Configuration of control objective modules is obtained by using standard routines and programming control objectives directly in Fuzzy Control Language (FCL).

Table 2.2: FLS Automation in Copenhagen

Control Systems:
Cement Systems
Industrial Systems
Instrumentation
Process Computers:
fuzzy logic control
Qualitative control by computer and X-ray (QCX)
Expert Control Systems (ECS)

Fuzzy II developed since 1990 (Table 2.4) is being marketed by FLS Automation as a new generation high level kiln control. It emerged from the company's experience with the previous fuzzy logic control

systems. More precisely, it builds on the experience of nearly 100 high level kiln control systems supplied by FLS. Table 2.5 shows some of the applications of FUZZY II.

Table 2.3: Systems produced by FLS

System type	**Description**	**examples of products/applications**
SDR systems (over 200 supplied)	Computer-based plant control and regulation systems for Supervision, Dialog, Reporting.	o **SDR/CemScanner**: a system based on an infrared line scanner to measure the temperature of fast-moving surfaces such as a rotary kiln shell. o **SDR/Fuzzy Logic**: a Fuzzy Logic based expert system for automatic control of complex processes based on the operator know-how. o **SDR/OpStation**: Operator Station for use in connection with PC--based control systems. o **SDR/PowerGuide:** planning, monitoring and control of electrical energy
QRX Systems (over 100 supplied)	Quality control by computer and X-ray, in automatic laboratories for controlling raw mix composition particularly at cement plants.	o sampling of pulverulent or lumpy bulk materials; o automatic pneumatic conveying of samples; o manual and automatic sample preparation; o fully automatic sample preparation; o control and registration of data from analysis instruments (X-ray spectrometers, X-ray diffractometers, laser granulometers); o data utilization for specialized control applications and for quality control reports
advanced measuring systems (more than 50 systems are supplied every year)	systems tailored to specialized measuring applications such as analysis of gases under extreme conditions (1200C) and high dust concentration	o temperature monitoring from rotary kilns; o TV monitoring of cement kiln and cooler processes; o filling ratio of cement mills SDR/CemScanner for monitoring kin shells.
cement industry applications	system packages based ion standard process control products of various makes	o **SDT/FuzzyLogic** for kiln, cooler and mill control; o SDR/CemScanner for kiln shell monitoring; o **QCX** for laboratory automation
SCADA systems	systems for Supervision, Control, Data Acquisition for power stations, gas and oil production facilities	SCADA system for manned and unmanned installations
environmental protection systems	pollution control, regulation and monitoring systems for incineration plants, flue gas cleaning installations at power stations	o **SDR/Fuzzy Logic** for optimizing overall operation of incineration kilns; o SDR/CemScanner for monitoring the shell temperature of incineration kilns
paper industry (supplied in Sweden, Finland, USA, Canada, Indonesia, Poland)	control systems for chemical recovery at paper mills	o **SDR/FuzzyLogic systems** for overall control of lime-burning kilns and lime slaking facilities; o **SDR/CemScanner** for monitoring lime-reburning kiln temperature.

Table 2.4: A brief history of QCX products at FLS Automation:

mid'70s:
Starts the work on automatic kiln control

1980:
First high level kin control system becomes commercially available and is supplied by FLS Automation

1981:
First version of the Fuzzy Logic Control system

1982:
First Fuzzy System for kiln process control (Oregon, USA).
The high level language FCL was introduced
From this moment on work has been towards improving the fuzzy system approach; **no real innovations in automatic kiln control have been presented since FLS introduced and demonstrated the first computer based systems using rules and fuzzy logic for implementation of kiln control strategies**

1984:
Second version of FCL

1986:
Fuzzy control of mills

1987:
Fuzzy control for kiln start-up
Fuzzy grate control

1988:
Starts work on the second generation fuzzy control system: Fuzzy II

1990:
Fuzzy II deployed

1991-1994:
Fuzzy II in operation :
- four new systems
- ten upgrades

Table 2.5 Example of applications of FUZZ II

Lime burning kilns	Causticizing Control

Control Strategy	**Two control groups:** o fire-end control: to produce lime of good quality (target value of residual carbonate; o Stable operation and quality control are produced through adjustment of the kiln speed and also by changing fuel rate o feed-end control: most important reflecting the fact that optimal control requires correct and stable conditions at feed-end; it includes: o control of feed-end temperature: control of oxygen; o production control: control of abnormal situation like cleaning of lime and mud filter; o Control actions are executed on: I.D. fan speed, lime and mud flow, fuel to the kiln , kiln speed. o The setpoints are adjusted automatically. o Modifications of the control system are usually not necessary; o Start and stop of machinery, interlockings and alarm treatment **are the same as before Fuzzy II** was installed	**One control group:** o Control objectives are divided into those for normal operations and for abnormal operations. o Control objectives for normal operation: stable operation o product quality: Fuzzy II uses for example alkali analysis, the causticizing efficiency and/or other quality measurements. o production control; o Basic principle of the control strategy: calculate automatically the relationship between the product quality measurements and one or two continuous measurements (e.g. conductivity, slaker temperature). **Based on these Fuzzy II takes corrective actions on the lime stone feed and green liquor flow.** o strategies for abnormal situations such as for: very high slaker temperature, abnormal product quality test.
Measurements	Same measurements and control parameters as for manual control: o oxygen at feed-end o CO at feed-end o lime mud density o feed-end temperature o feed-end pressure o fire-end temperature o fire-end pressure o mid-zone temperature o residual carbonate test oThe standard control parameters: - speed of ID fan and/or - position of exhaust gas damper - lime mud flow - kiln speed	Same measurements and control parameters as for manual control: o conductivity o slaker temperatures o product quality - active alkali - causticizing efficiency etc. o green liquor density o level of burnt lime in silo o The standard control parameters: - green liquor flow - lime stone feed - make-up lime stone feed
Interface to process	The FLS-SDR software platform is connected to the process through a serial communication link, either by using an existing port or by installing a small PLC between the control system and the SDR platform	The FLS-SDR software platform is connected to the process through a serial communication link, either by using an existing port or by installing a small PLC between the control system and the SDR platform
Software extension	The complete set of Fuzzy II control modules for the Pulp and paper industry includes: o **Fuzzy II Causticizing Control** o **Fuzzy II Production Flow Control** o CemScanner system for Kiln Shell Temperature Monitoring (based on PC and workstations)	The complete set of Fuzzy II control modules for the Pulp and paper industry includes: o **Fuzzy II Lime Burning Control** o **Fuzzy II Production Flow Control** o CemScanner system for Kiln Shell Temperature Monitoring (based on PC and workstations)

We review next, the motivation behind, and characteristics of Fuzzy II system.

The success of the first fuzzy systems depended on several human factors. This was stated in reports evaluating these systems, and verbally by the designing engineers. Thus, the qualifications and experience of the commissioning engineers, and the commitment from the plant personnel seem to have

played an important role towards successful exploitation of these systems. The human factor is important when one recognizes that a control strategy is optimal for only a limited period of time and therefore, maintenance is necessary; that even optimal control strategies will fail without proper maintenance, which is bound to happen when maintenance is too complicated.

FUZZY II is an expert system with a well-defined structure. The two most important features of this system are **objective modules**, and **priority management**.

Like its predecessors FUZZY II includes rule definition and programming facilities, but in addition, it includes a unique design feature - that of objective modules. As the name suggests these modules are meant to ensure that certain objectives are attained. Examples of objectives include the more traditional ones, such as setpoints on measurements, but the really novel feature is the **high level objectives,** such as **stability, optimal production, calculations that involve process modeling, etc.**, as illustrated in Table 2.6.

Table 2.6. Examples of kiln control objectives

Type of objective	
Simple	**Advanced**
NoCO	stable operation
Oxygen at setpoint	correct clinker quality
high NO_X limit	maximum production
kiln amps at setpoint	stop cycling
etc.	etc.

It is to note that these objectives, especially those in the advanced column of table 1.6 are by excellence fuzzy. Strategies must be designed to fulfill these objectives, but as it can be expected such strategies will often be in conflict.

The **priority management** module ensures that each objective has a priority which is taken into account for the final strategy. Objective modules, as illustrated in Figure 2.2 are associated to each control objective.

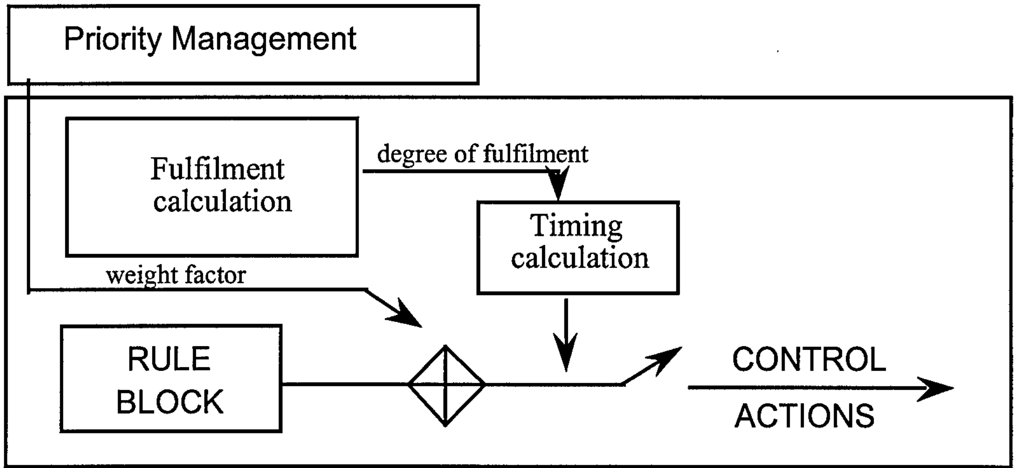

Fig. 2.2: Fuzzy II: Control Objectives Module

The fulfillment calculation evaluates **the degree to which the objective is fulfilled; the results are values in [0, 1], expressing how close the actual process situation is to the objective.** The actual calculations depend on the type of objective. FUZZY II is capable of performing calculations for a wide variety of kiln control objectives.

With respect to the rule block, FUZZY II offers flexibility, in that rules from one system can be easily transferred to another system. The actual calculations depend on the type of objective. FUZZY II is capable of performing calculations for a wide variety of kiln control objectives.

With respect to the rule block, FUZZY II offers flexibility, in that rules from one system can be easily transferred to another system. **But the uniqueness claimed by FLS for FUZZY II lies elsewhere:**

- **the structure of the system: the overall control strategy is divided into sub-strategies, each of which corresponds to a control objective.**
- **the knowledge about the optimal interaction between the rule blocks is built into the priority management.**

This approach, coupled with the design tool and predefined structure of FUZZY II has shown that a new control strategy is approximately 50% completed **before** the actual programming started.

The priority management is based on a weight factor associated to objectives; this ensures that control actions are executed if the more important objectives are in a reasonably good condition. Given an objective its weight will be closer to 1 according to how close to 100% fulfillment are the objectives which have a higher priority. If one of these is not fulfilled then the control actions to satisfy the objective will be reduced.

Timing calculations is another very important aspect: it determines when a control action must be executed and how long to wait before execution of the next adjustment. In FUZZY II timing calculation

is attached to each objective - such that individual time delays and constants as necessary for each objective can be taken into account. Most importantly, the fuzzy paradigm can be exploited here by making timing calculation a function of the degree of objective fulfillment: more frequent control actions are needed, and hence taken, if the degree of objective fulfillment is low. In other word, actions are taken as necessary.

Results and evaluation of FUZZY II :

The new concept of FUZZY II has evolved from practical experience with practical problems, related to process control (in particular control of cement kilns, incinerators, etc.). It has been extensively tested and evaluated on processes at paper mills, cement and lime-burning kilns.

When older systems were converted to FUZZY II comparative "before and after" studies have shown the following improvements:

o higher-run factor (typically an improvement by 10-15%

o improved control performance

o easy maintenance through a better understanding of the control strategy.

In completely new systems the impact of FUZZY II seems to be even more striking. By comparison with other high level control systems the advantages of FUZZY II are:

o predefined control strategy structure, modular such that modules can be added and deleted as necessary;

o knowledge about module interaction built in a priority management system;

o easy initial configuration on the basis of available process knowledge; the more specific this knowledge is the more the initial configuration will correspond to a good starting point.

o most important of all is the easy maintenance aspect which is a direct result of the modular approach.

Fuzzy logic control of waste incineration

Building on its experience in the high level control of cement kilns, and on the fact that cement manufacturing and waste incineration are both examples of complex processes, FLS Automation has

successfully implemented fuzzy logic control in waste incineration (non toxic industrial and household waste and hazardous waste).

In fact, this work is part of a larger effort of FLS Automation to export its expertise in high level control to non-cement industries.

Incineration of hazardous waste: In this area FLS Automation is working with Komunekemi A/S based in Nyborg, which specializes in incineration processes of many types of oil and chemical waste. In addition to obtaining a more efficient incineration process, easier process management and shifting from one type of waste to another have been obtained.

Incineration of general household and industrial waste: FLS Automation has worked on high level control of this process with I/S KARA at their incineration plant in Roskilde (which I had visited) After a pilot project ran successfully during the early 1990's a full system has been installed.

In both cases the impact of the work is likely to go beyond the immediate profits of the companies involved, as international marketing schemes are pursued by FLS Automation and Chemcontrol (a subsidiary of Kommunekemi) and by FLS Automation and I/S KARA. The immediate targets are Germany, and the Scandinavian markets. but also the rest of Europe. FLS Automation has compiled a directory of more than 100 sales references for fuzzy logic controllers it has supplied, and an the basis of their successful operation has concluded that fuzzy logic offers an efficient control strategy.

Conclusion

FLS Automation has been the first to implement fuzzy logic control in an industrial applications, accumulating perhaps the largest amount of expertise in this field. During my visit there I was told that the priority of the company is to remain competitive in the area of industrial control systems (especially for process control), and that **the use of fuzzy logic has enabled them to maintain a substantial edge in this respect**. On a lighter note, I was told that it took some internal debate and deliberation before the company has actually decided to use the term "fuzzy" in a product name. Due to the performance of these systems, and to the more recent increased interest in the fuzzy logic based technology, FLS Automation feels that it has made a very good decision in preserving this term.

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Related bibiliography

Molbak T., Ostergaard J.-J., Lomholt F., Jensen F. Fuzzy Control for Optimization of Flue Gas Desulphurization Plant - A Report from the Real World. EUFIT'95, August 28-31, 1995, pp.965-969.

Ostergaard J.-J. Fuzzy Control of cement Kilns - A Retrospective Summary, EUFIT'93 Aachen, Sept. 1993, pp. 552-558.

3. Research on Management of Uncertainty in Intelligent Systems at LAFORIA (LAboratoire FOrmes et Intelligence Artificielle) Paris, France

General information

- o LAFORIA is a research laboratory attached to the University Pierre et Marie Curie (Paris VI), considered the foremost scientific University in France;
- o LAFORIA is associated with the CNRS (National Council for Scientific Research);
- o LAFORIA was the first laboratory in France devoted entirely to Artificial Intelligence.

Table 3.1 shows the budget sources for LAFORIA during the years 1992-1994.

Table 3.1: LAFORIA Budget (distribution and evolution)

Year	Total	Funding sources								
		Univ. Paris 6	CNRS	IBP	Tuition	PRC-GDR	Large national programs	EC&Int'l coope-ration	Public establish-ments	Industrial contracts
1992	4,838,848 F	33%	4%	4%	8%	4%	20%	5%	13%	9%
1993	4,382,858 F	35%	5%	3%	7%	7%	15%	14%	9%	5%
1994 (through 6/1/94)	3,290,299 F	43%	6%	5%	12%	3%	7%	12%	5%	5%

Research staff

LAFORIA has approximately 40 researchers who, in addition to their research give university lectures and other specialized doctoral courses. In addition, there are approximately 100 PhD D students

including industrial grants holders[4] (approximately 35%) and research ministry grant holders (approximately 30%).

The research output, scientific papers, are published in specialty journals (a typical figure is around 60 per year) and conference proceedings (typically about 50 per year).

The research staff is also engaged in:

- o editorial activities of approximately 20 journals specialized on different aspects of intelligent systems;
- o doctoral students supervision: 15 to 20 PhD theses are submitted per year.

The Doctoral School

LAFORIA's contribution to doctoral studies takes place within the Doctoral School of the Institute Blaise Pascal. The following programs are offered through LAFORIA:

DEA (Diplome d'etudes approfondis): post-graduate-pre-doctoral program

DEA in AI-PR and Applications :

This program in Artificial Intelligence and Pattern Recognition, (the French acronym being IARFA) offers a very wide range of specialized lectures in AI, theoretical aspects (logic, languages, cognitive science) and applications (expert systems, learning, fuzzy logic, neural networks, speech recognition and synthesis). The number of students in this program is typically around 80.

DEA in Cognitive Science

This joint program of Ecole des Hautes Etudes en Sciences Sociales (EHESS), Universite Pierre et Marie Curie and Ecole Polytechnique, administered by LAFORIA, involves various disciplines related to the study of natural and artificial cognition, from biological aspects to formal structure.

DEA Data and Information Processing

LAFORIA is associated for this program located and administered by University Paris IX (Dauphine).

Specialty Schools

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[4]The industrial collaboration works as follows: a PhD student receives the equivalent of a graduate scholarship from an industry; PhD students adviser receive from the corresponding companies a certain amount of money for each PhD student they advise. PhD theses addresse usually problems of strong interest to the sponsor company.

These consist of a post-graduate pre-professional Program (DESS) whose goal is to prepare engineers or future engineers in the latest technology.

GLA[5] is the DSS program in Applied Software Engineering. Teaching within this program is organized around a one year project based on techniques from artificial intelligence, functional languages, object oriented languages (Lisp, Prolog, Small Talk, C++), operating systems (UNIX, Windows, etc.)

IA is the DESS program in Artificial Intelligence. It is organized around three themes: representation and use of knowledge; applications (database, expert systems, pattern recognition, learning environments); software kits for AI.

International and Industrial Collaboration, National Research Programs

LAFORIA is involved in several European projects including:

o EUREKA, FORMENTOR, tools for the prevention of risks, and incidents decision aids in dangerous industrial situations.

ESPRIT (II, III, IV framework):

- o Network of Excellence - Machine Learning
- o VITAL on knowledge acquisition methods
- o **ERUDIT - excellence network on uncertainty issues** (mainly dedicated to fuzzy logic-based technologies).
- o PECO - Community Action for Cooperation in Science and technology with central and Eastern European Countries - Techniques and methods for developing business expert systems; Convergence properties of neural network classifiers.

Within the national programs LAFORIA is active in PRC Artificial Intelligence, PRC Spoken Communication, GDR Genome Computer project, Genome Study and Research Group, Cognicenter Network, GDR Control Engineering.

Research Directions

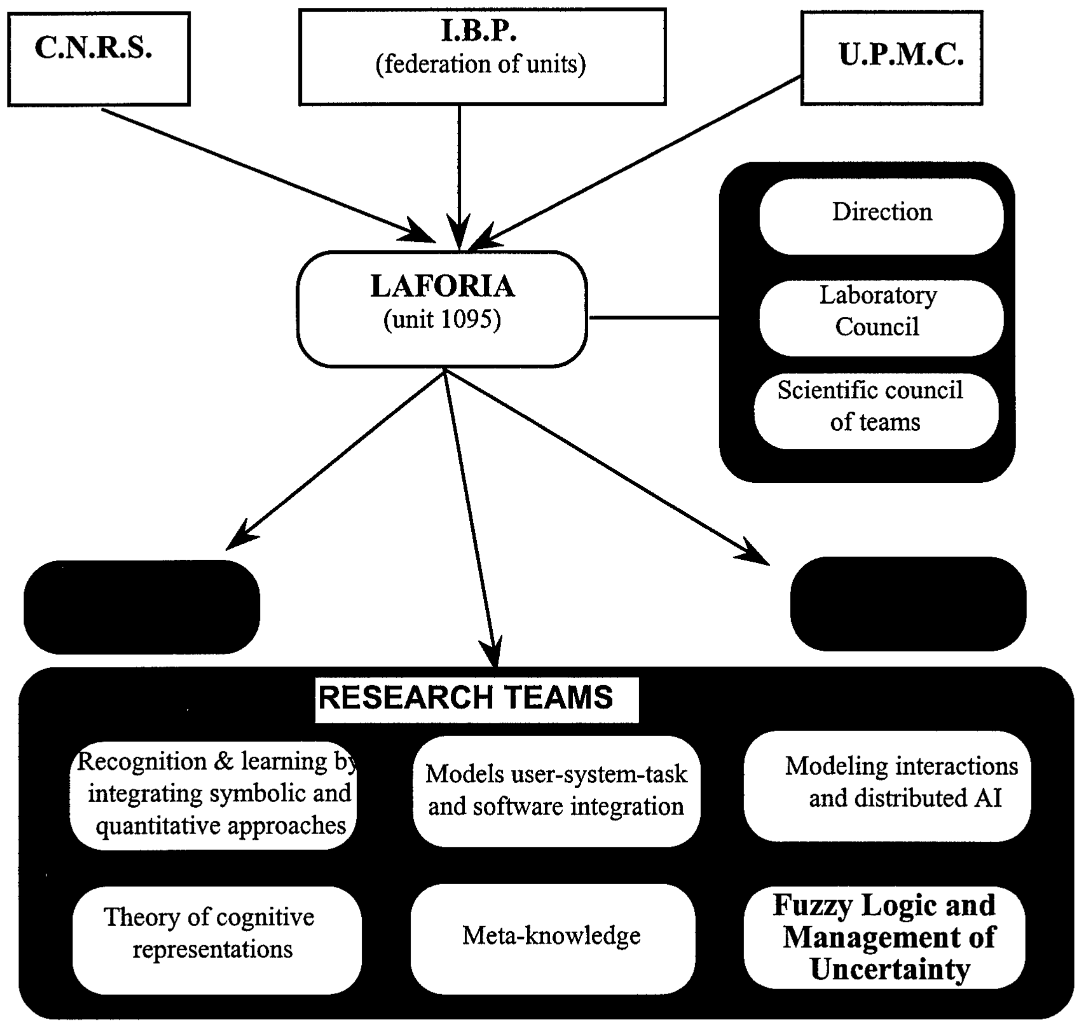
The research activities of LAFORIA are organized around six themes (see also Figure 3.1) covering aspects of recognition and learning by integration of the symbolic and the numeric paradigms:

- o Interaction modeling and Distributed AI
- o **Fuzzy Logic and Management of Uncertainty**
- o Meta-knowledge

[5]Gestion Logiciel Appliquee

o User-System-Task Modeling and Software Integration

o Cognitive Science



C.N.R.S: National Research Council
I.B.P.: Institute Blaise Pascal
U.P.M.C.: University Pierre and Marie Curie

Fig. 3.1 LAFORIA's structure and place as a CNRS research unit and its six research programs

In the following the research done in fuzzy logic is discussed:

Fuzzy Logic and Management of Uncertainty (LOFTI)[6]

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[6]This acronym, corresponding to the French name of the group - Logique Floue et Traitment d'Incertitutdes - plays on the first name of the man who invented fuzzy sets/logic, Lotfi Zadeh, which is often misspelled as Lofti.

The leader of the program is Professor Bernadette Bouchon-Meunier, Director of research at CNRS. The group has approximately 12 PhD students and two other individuals on its research staff. Four of the PhD students spend more than 80% of their time at LAFORIA while the remaining spend at least 80% of their time in companies or other enterprises.

Research problems

The problems considered by this group arise from the fact that often the data under consideration in an intelligent system are fraught with different types of *imperfection* such as

- *uncertainty* due to doubts about the validity of a measurement or the truth of a statement;

- *imprecision* due to poor sensors or measurement equipment, or due to vague descriptions such as those typically given by human beings, experts, operators, or novice observers of a phenomenon;

- *incompleteness* issued from treatment of very general information, eventually subject to exceptions, or from the lack of information on an aspect of the system studied.

In any case, these imperfections, cause problems at all levels of an artificial intelligence system. More precisely, the *acquisition* of imperfect knowledge and its *representation* pose difficulties and require special treatment - typically by integrating symbolic and quantitative approaches. This is especially possible in the framework of fuzzy logic and theory of possibility based on it. In this framework data expressed in natural language by human observers and data obtained by sensors or other measurement instruments can be easily integrated; general categories given as symbolic descriptions can be exploited in the presence of particular cases, whose characteristics are known precisely.

Finally, the last level of difficulty posed by imperfect data (in the sense described above) is in the *exploitation* of an artificial intelligence system. In particular when reasoning is needed in an expert system, decision support system, diagnostic system, or control system.

The research done by the LOFTI team concerns all the three aspects mentioned above.

Direction of research

The use of fuzzy logic, possibility theory and information theory are the main directions of the research carried out within this group. The theoretical basis of all methods used are thoroughly investigated.

The work covers:

- problems of concepts with ill defined boundaries,
- aggregation of imperfect information,

- o fuzzy relations for representation of imprecise resemblance,
- o methods of fuzzy reasoning

With respect to knowledge acquisition the following problems are being addressed:

- o learning from examples in the presence of imperfections
- o knowledge acquisition methods for expert systems, user interface.

In the area of interface the work centered on semantic networks for on-line support for a user expressing him/herself in terms unknown to the system.

For representation purposes the use of *fuzzy subsets, linguistic modifiers* able to account for gradual nature of concepts, as well as the use of *fuzzy rules* for expert knowledge representation are under investigation. In connection with the latter the very important issues of robustness of the rule parameters are addressed.

The group also works on object oriented versions of numerical algorithms, such that these algorithms could then be adapted to deal with imperfect data.

Work on fundamentals of *fuzzy logic-based reasoning* methods is a strong component of the work on this group. In particular it addresses the selection of mathematical devices for approximate reasoning, and extensions of the case based reasoning (CBR) to imprecise knowledge, using a *fuzzy relations* formalism.

Important issues in *fuzzy control*, are approached by viewing this as a particular case of knowledge based systems. This also includes the general mathematical framework for studying the issue of stability of fuzzy control.

Main Results

Knowledge Representation in a Fuzzy Framework

Gradual knowledge, so easily expressed by humans is very difficult to express and manipulate in a computer. A fuzzy logic based approach can use the progressive (gradual) character of the membership function, on one hand, and of the logical operators on the other hand, notably the implication operator able to model a "loose" connection between classes.

Linguistic modifiers

Results in this area include modeling statements of the type

X is mA

where

X is a variable (such as temperature for example),

A is a fuzzy set defined on domain of X (such as elevated) and

m is a linguistic modifier (such as really, relatively, etc.

The treatment of linguistic modifiers developed results in adaptive modifiers allowing a smooth transition between categories to which they are attached, reinforcing or weakening the fuzziness of the category as a given context may require.

Different forms of graduality - *local and global graduality* - regarding the certainty and imprecision, respectively, of a statement have been defined. As a consequence fuzzy implication operators have been classified according to the type of graduality that they support[7].

The work on graduality has also led to work on *possibilistic and fuzzy semantic networks*. In collaboration with the cognitive psychology laboratory of University of Paris VIII, these are used for developing dialogue interface with a novice learning to use a new technology. Results of this work have been implemented in the SIFADE system[8].

Modeling of complex systems

Fuzzy sets theory and fuzzy logic have proved very efficient in modeling complex systems. Characteristic to these is the fact that complexity and ability of describing these systems are strongly related (recall Zadeh's principle of incompatibility). *Fuzzy numbers, fuzzy relations, fuzzy graphs* were used in developing algorithms effective even when both uncertainty and imprecision in the data were present. The work resulted in a *prototype system for preparing an air mission*, in the framework of a military project. An algorithm for trajectory optimization in the presence of fuzzy constraints has been developed and implemented[9].

In a different direction, namely that of modeling human behavior (as opposed to mechanical systems/process) work has been carried out *on modeling of facial expressions*[10] [11].

Transformation of numeric algorithms.

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[7] Bouchon B. et al, Linguistic Modifiers and Imprecise Categories, International Journal of Intelligent Systems 7 (1992) 25-36.

[8]Omri M.-N Interface homme-machine acceptant l'imprecision, Congre INFORSID'93, 1993 Lille (in French).

[9] Kelman A., Optimization floue de trajectoire, preparation de mission aerienne, Journees nationales sur les applications des ensembles flous, Nimes, 1993.

[10]Ralescu A., Hartani R., Modeling the perception of facial expressions based on a fuzzy logic approach, IPMU Paris, 1994;

[11]Ralescu A., Hartani R. Reasoning about the transition between facial expressions, 3rd IEEE International Workshop on Robot Human Communication, Nagoya 1994.

Fuzzy and crisp data may appear in given problems, in which case exact algorithms (assuming that they exist) must be adapted to handle fuzzy data. Rather than adopting a problem dependent approach a more general one addressing the problem of equivalence of algorithms has been adopted.

Object oriented modeling of numerical analysis algorithms has been used to develop rules of re-writing an algorithm into an algorithm equivalent to the initial one, but able to handle data of different types. The approach has been used in a project with The French Electricity Board[12] to develop a tool kit to support the development of scientific programs[13].

Exploiting imperfect knowledge - Fuzzy expert systems

In the area of expert systems in which the group has been very active for a considerable number of years, the following problems have been addressed: analogic reasoning, fuzzy questionnaires, fuzzy control.

Analogic Reasoning

Starting with fuzzy *similarity relations* (similarity relations, already defined within the theory of fuzzy set, are symmetric, reflexive and transitive) *resemblance relations* have been defined.

Resemblance relations are obtained by a weakening of similarity relations, in the sense that they are not symmetric and satisfy a weak transitivity. Formal definition of the resemblance relations started from triangular norms (these are operators generalizing logical operators). A link between the use of such relations and fuzzy implication operators, also defined from triangular norms has been established. The results of the analogic reasoning are either qualified by uncertainty, or they are deduced from known characterizations, via linguistic modifiers. In any case they can be expressed in a linguistic form, based on known characterizations[14].

Fuzzy questionnaires

B. Bouchon has worked since mid-seventies on a theory of *branching questionnaires*. When used with the branching questionnaires fuzzy similarity relations affect the identification of an event. In this framework it is considered that there is a finite collection of events, that these events are not necessarily absolutely distinctive and the similarity relation is used to quantify their resemblance. Taking into account uncertainty and similarity *an entropy measure* is defined and used in decision trees[15]. The notion of *conditional entropy* has also been introduced and is being used in a framework of inductive learning.

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[12]EDF - Electricite de France
[13]Bakhouch M. Program Transormation System for Software Reuse. IPMU, Paris 1994.
[14]Bouchon B., Valverde L., Analogical Reasoning and Fuzzy resemblance, *in* B. Bouchon, L. Valverde, R. R. Yager (eds.) *Intelligent Systems with Uncertainty*, Elsevier, 1993.
[15]Bouchon B., yager R. R. Entropy of similarity relations in Questionnaires and Decision Trees. Proc. FUZZ-IEEE'93 San Francisco, 1993.

Fuzzy Control

As mentioned often in this report, fuzzy control accounts for the success of fuzzy logic in industrial research laboratories, and for the renewed strong interest in fuzzy logic throughout the world. In the LOFTI group the work on fuzzy control has centered around theoretical issues, the most important of which are *stability* and *robustness.*

- o Stability seeks to characterize the influence on the output of the system of perturbations in the input data.

- o Robustness concerns the lack of change in the system's behavior when the parameters of the system are perturbed.

The basic approach adopted by this group, in addressing both the issue of stability[16] and robustness[17], is that of fuzzy control based on *fuzzy relations* and *fuzzy graphs*.

Implementations of fuzzy control used to illustrate the applicability of the theoretical results were developed in the following areas:

- ◦ management of telecommunication network[18],

- ◦ global supervision of a transport network (in collaboration with INRETS[19] and the group LAFORIA - Recognition and Learning by Integration of the Symbolic and the Numeric[20]).

Acquisition of imperfect knowledge

Learning from imperfect examples

Examples whose attributes have mixed values (numeric or symbolic), and/or for which these values are imprecise are considered in these studies. For such example sets the classic inductive learning methods based on the construction of decision trees are not satisfactory.

The first extension of such methods were to the case when fuzzy sets were used as attribute values, providing thus for the attribute value a symbolic and numeric representation. A new concept of *entropy*

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[16]Wontcheu T. Y. Operateurs flous et applications a la conception des regulateurs puor la command des systemes flous, Journees nationales sur les applications des ensembles flous, Nimes 1992.
[17]Gouyou F. Robustness des systemes a la commande floue, Raport Interene CEPEM, DRD9304003, 1993.
[18]Khalfet J. et al. Application of Fuzzy Control to adaptive Traffic routing in Telephone Netwroks, QUARDET'93, 3rd International Workshop on Qualitative Reasoning and Decision Technologies, Barcelone, 1993.
[19]INRETS: National Research Institute of Transports and their Safety.
[20]Hartany R. et al. Modelisation of a Subway Regilation Systembased on Neural Networks and Fuzzy Logic Approach, IFAC International Congress, Beijing 1994.

has been introduced in this connection helping to identify the fuzzy set representation most informative towards taking a decision[21 22].

Similarity relations have been used in this context in two ways:

- for smoothing the distinction between the final decisions of the learning, expressing a *relative indifference of the decision maker* with respect to the neighboring classes; In this case the results mentioned above on the entropy taking into account similarity and uncertainty have been exploited during the construction of the decision tree.

- for mediating the difference between the values which can be taken by an attribute; In this case fuzzy quantifiers ,such as most, a few, have been used to extract a similarity relation on the example set, such that a general behavior of examples characterized by different values (e.g. small, medium) of the same attribute (e.g. size) can be obtained. This similarity relation leads to anew attribute value eventually obtained by *an aggregation* of the two values, finally simplifying the example base[19] .

It must be emphasized here that the new concepts/tools developed, such as entropy, similarity relations, can be used in contexts other than that of inductive learning which motivated them originally.

Fuzzy - neural approaches

As other researchers in the field, the group LOFTI is investigating the integration of neural network methods and fuzzy logic. In particular, one of the most important aspects is that of using the generalization capability of neural networks for identifying the parameters of a fuzzy system[20] .

Neural Networks have been also used in an algorithm of refining a knowledge base. The data used are imprecise and/or symbolic as is often the case in fuzzy control systems. Applied aspects of this work have been integrated in a support system for quality control in the automotive industry developed in conjunction with PSA[21 22] .

Conclusions

This section has presented some of the work done within the group of uncertainty management and fuzzy logic at LAFORIA. The group led by Bernadette Bouchon-Meunier is perhaps the best known in

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[21]Ramdani M. Double description numerique-symbolique en apprentissage, Journees nationales sur les applications des ensembles flous, Nimes, 1992.

[22]Ramdani M., Apprentissage a partir de donees imparfaites, Congres AFCET'93, Versailles, 1993.

[20] Hartani R. PhD Thesis, June 1995
[21] Peugeot Simca Automobiles - automobile maker
[22] Menage X., Hartani R., Syntheses des methodes d'association des techniques Neuronales et des techniques floues, LAFORIA 93/23, 1993.

France, as the only well established group in the Paris region, and covering theoretical and practical work often from inventing the mathematical concepts needed to software implementations.

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4. Intelligent signal interpretation at LAMII - Laboratoire d'Automatique et de Microinformatique Industrielle - Centre des Sciences Appliquees a la Production - University of Savoy, Annecy, France

General information

Laboratory for Automation and Industrial Micro Informatics - Center for Sciences Applied to Industry - University of Savoy, School of Engineering, Annecy.

Created in 1983, LAMII is one of the five laboratories of the Higher School of Engineering of Annecy, one of the older components of the Savoy University.

At the end of 1994 its research staff of 50 included (Table 3.1) 14 permanent research-teaching professors and 17 PhD students, the remaining comprising non tenured staff.

Table 3.1 Research Staff at LAMII

	1993	**1994**
Permanent staff	13	14
Doctoral students	15	17
non tenured	5	11
ATER PhD	1	5
Total	**34**	**47**

The non tenured category includes DEA students, long-term visitors.

Themes of research: process automation, machine vision and sensors carried out within four research groups as follows:

- o Expert control,
- o Conception and management of Manufacturing Systems,
- o Advanced Control Techniques,

o Industrial Vision.

Projects are mainly of applied character; for more theoretical issues LAMII collaborates with several research units (Table 3.2). Locally these include Center of Science applied to Industry, The Laboratory for Measures in Fero-electricity and Optics of Annecy, Laboratory of Applied Mechanics, Laboratory for Industrial Software, etc. At the regional level, collaborations are with the Laboratory of Automatics of Grenoble (LAG), in the domain of Artificial Intelligence - supervising DEA theses; the Laboratory of Industrial Automation (LAI) of the National Institute of Applied Science (INSA) of Lyon, in the field of nonlinear systems and industrial vision (this collaboration also includes a German partner The Institute Fraunhofer IITB of Karlsruhe).

On the national level, LAMII participates in two in the group nonlinear DRET and the group on fuzzy logic of the French Observatory for Advanced techniques.

Finally, on the European level LAMII belonged to the working group FALCON (of the program ESPRIT III) (FALCON WG 6017) dedicated to Fuzzy ALgorithms for CONtrol.

The Center for Industrial Applications of Sciences (CESALP): Comprising the laboratories mentioned above (LAMII, LLP, LMecA, LAMFON) CESALP was created in 1992 in order to provide the basis for sharing and managing resources between the four member laboratories and to organize their research themes around a central, global theme: functioning of industrial enterprises.

Table 2: Collaborations with the socio-economic sector

Enterprise	**Type**	**Object**	**from**	**to**
ALCATEL	research contract		10/93	9/96
ELF	advising	fuzzy regulation of flow	03/93	12/93
ESPRIT III	WG FALCON 6017	Fuzzy Algorithms for CONtrol	9/92	8/95
GENOMIC	research contract	Filtering and Image analysis	04/91	06/94
LASER Metrologie	research contract	System for measuring laser strength	01/93	07/93

MESR	Research Initiative	evaluation of several methods for robust and intelligent management in manufacturing	12/94	11/96
The Region Rhone-Alpes	Research programs	Robust and Intelligent management in manufacturing	12/94	11/97
SERT	research contract	Fuzzy regulation of the continuos steel flow	05/93	05/94
TELEMECANIQUE	commercial contract	Fuzzy Sensors	03/94	03/94
VERTOREX	commercial contract	Predictive control	10/94	10/94

For this report we are interested in the research involving fuzzy logic methods. Professor Laurent Foulloy's and his student's work in this area has attracted a great deal of attention starting with 1993.

The work in this area aims at developing new methods for process control so as to allow taking into account knowledge about the process to be controlled. This knowledge expressed as IF-THEN rules is used in conjunction with a fuzzy reasoning mechanism. Fuzzy Reasoning methods are applicable to the control but also to data extraction (measurement) by sensors. Thus two main themes have been developed:

o **fuzzy sensors**

o **fuzzy control**

Not only do these themes rest on common techniques, but they are related by a "supply-demand" type of relation, as a fuzzy controller assumes/demands the type of (fuzzy) data which are the output of the fuzzy sensors.

Fuzzy sensors

The starting point in regard to fuzzy sensors is the fact that measurements play a fundamental role : in quality control, system supervision, analysis of system parameters with a view for their optimization. In this situations, the usual sensors, designed for operating in tightly controlled conditions is not suitable for handling variations in the measurements context. Hence, it is necessary to add an intelligent component to sensors. Such a sensor aims at attaining the following two objectives: improve the quality of measurements and yield information which can be integrated in a larger system including eventually other sensors, controllers and actuators.

To attain these objectives the following have been developed:

Theoretical level: a formalism for representation of symbolic knowledge. This consisted mainly on work for the conversion between numeric and symbolic knowledge representation. For this the framework of fuzzy logic has been adopted, and the basic knowledge representation paradigm was in terms of fuzzy IF-THEN rules.. The important problem of aggregation of additional linguistic information has been treated in this frame work as well, making use of an interpolative approach based on fuzzy partition of the universe sets associated to basic characteristics.

Practical implementation: hardware and software implementation which makes possible manipulation of required advanced concepts. The new functionality of the intelligent sensors both from the point of view of configuration, validity and cooperation and of ability to manipulate linguistic information have led to the definition of the concept of "fuzzy cell" (Fig. 4.1). This is designed around a 80C196 micro-controller, and several such cells are connected by a communication bus. The cells configuration is done in a file using a special purpose language called PLICAS. This language, compiled within each cell allows the manipulation of symbolic fuzzy data. This way high-level operations already carried out in the central unit are directly executed in the fuzzy cells, resulting in a better distribution of intelligence.

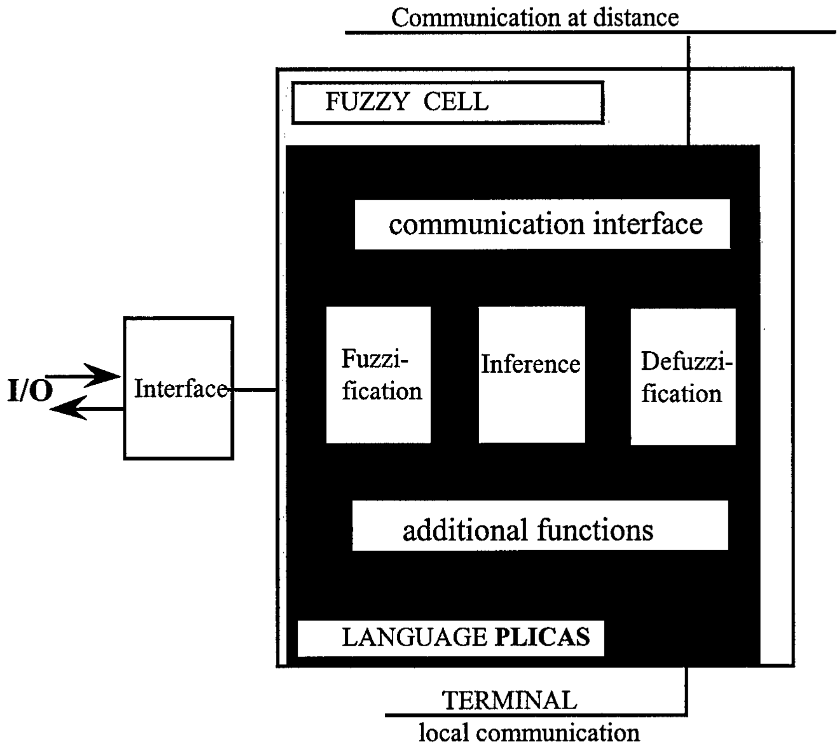


Fig. 4.1: Structure of a fuzzy cell.

The approach sketched above has been implemented in two sensors: a color sensor and a sonar sensor.

In addition to the micro-controller the color sensor consists of three photo-receptors to receive the light reflected by the illuminated surface, and realizing the description of the color by a fuzzy partition of the RGB space (Fig. 4.2):

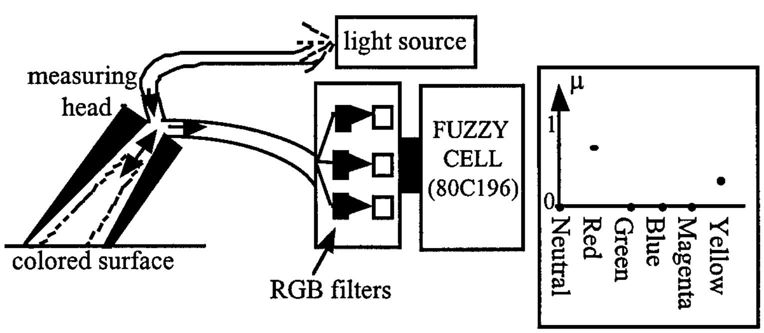


Figure 4.2: Fuzzy color sensor

The ultrasonic distance sensor takes as input knowledge of distances (expressed as fuzzy sets representing the labels small, medium, big) obtained by two receivers mounted one on each side of the sonar emitter and outputs the position expressed in linguistic labels such as left, right, in_front.

Fuzzy Control

The work on fuzzy control, strongly related to that on intelligent (fuzzy) sensor takes place under the following assumptions. For the design and implementation of a controller it is most interesting to be able to explore the totality of knowledge about the process to be controlled. This knowledge may include expertise, mathematical models, training data. In order to achieve this an approach which allows the integration of numeric and symbolic data is necessary. In this view fuzzy controllers provide the suitable framework as they allow, on one hand reasoning using a rule base, and on the other hand. With respect to the first - LAMII has addressed the problem of numeric-symbolic conversion, the result being a typology of fuzzy controllers; with respect to the second issue, LAMII has considered fuzzy implementation of classical controllers.

Typology of fuzzy controllers:

Three aspects are essential in the design of a fuzzy controller: fuzzification of the input data, inference and defuzzification. The types of fuzzy controllers identified at LAMII are obtained according to how these aspects are handled. The type of the controller depends on the choice of the sets on which the fuzzy labels associated to the input/output variables, yielding four different types of controllers. More precisely, if

- o X (respectively U) represent the universe of discourse associated to the input (output) variables;
- o L(Y) represents the collection of symbols associated to Y
- o F(Y) represents the fuzzy partition of Y

then the four types of fuzzy controllers correspond to combinations of operations shown in Figure 4.3:

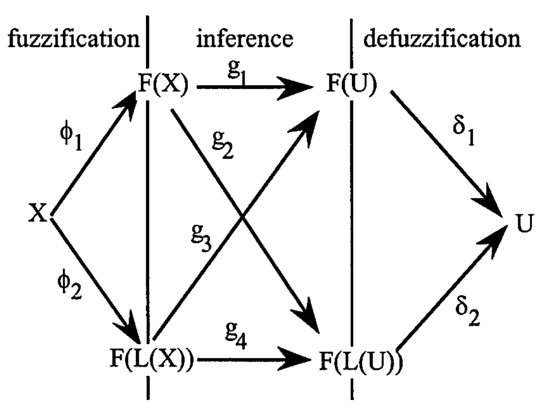


Figure 4.3: typology of fuzzy controllers

In the fuzzification step, ϕ_1 and ϕ_2 are called numeric and symbolic fuzzification respectively; similarly δ_1 and δ_2 are called numeric and symbolic defuzzification respectively. The type of a controller depends on the type of inference, g_i, i=1,...,4.

This typology allows one to classify the existent controllers. However, in addition it allows one to experiment with different implementations of the same controller. The four types correspond in effect to different types of expertise concerning a given problem.

Indeed, a purely symbolic controller (ϕ_2 and g_4) operates on a collection of weighted symbolic rules. This seems to be the closest to the representation of expert knowledge. In the work carried out at LAMII this type of controller has been used to the development of a system for regularization of a continuous flow of steel. In addition, in a type 4 controller the fuzzification, inference and defuzzification steps can be physically separated, each being realized by a specific component of the systems: fuzzy sensor, fuzzy actuator, or by a general component *fuzzy cell* configured for a specific tasks (fig. 4.4). The information exchange between various components is then symbolic and requires a relatively small volume of data.

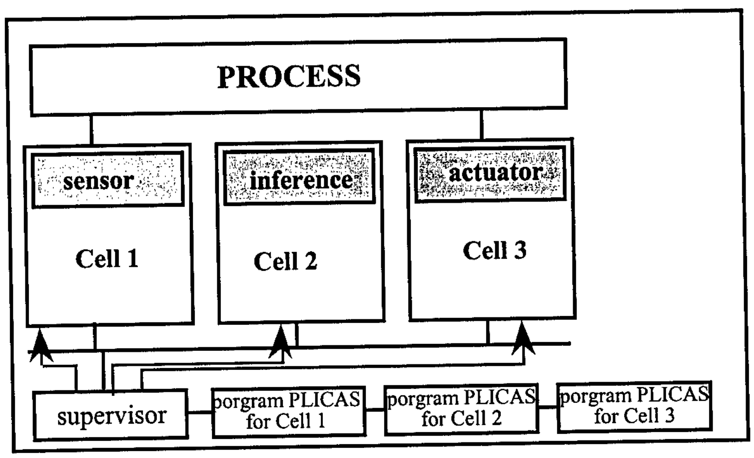


Figure 4.4: Network of fuzzy cells for process control

By contrast a controller of type 1, purely numeric is suitable for imprecise input values and hence, can take into account sensor imprecision. In its studies, LAMII has shown experimentally that the treatment of imprecise input, represented as a crisp or fuzzy set symmetric around a value, say x0, gives similar results to that in which the precise value x0 is considered. In other words, the result provided by a fuzzy controller, when the input is approximated by sets as shown in Figure 4.5 (a) is very close to the result obtained when a precise input (Figure 4.5(b) is used.

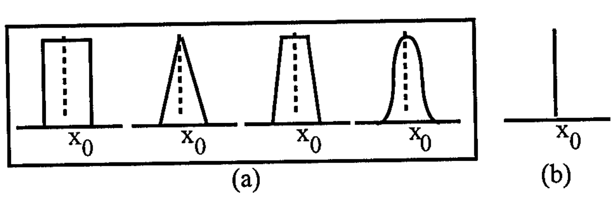


Fig. 4.5: Different forms of input for a fuzzy controller

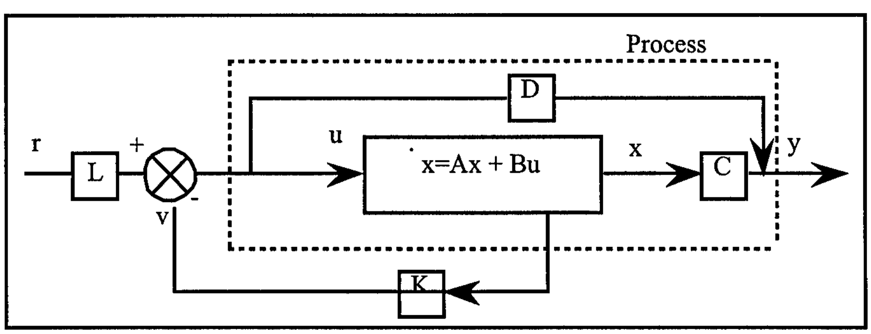
According to LAMII, the proposed typology has several advantages: it allows a structural analysis of the fuzzy controllers; a semantic analysis can be associated to the inference block; and this approach can be used to determine the semantic of the knowledge base, implicitly determined by the choice of the inference operators.

Methodology for implementation of fuzzy controllers

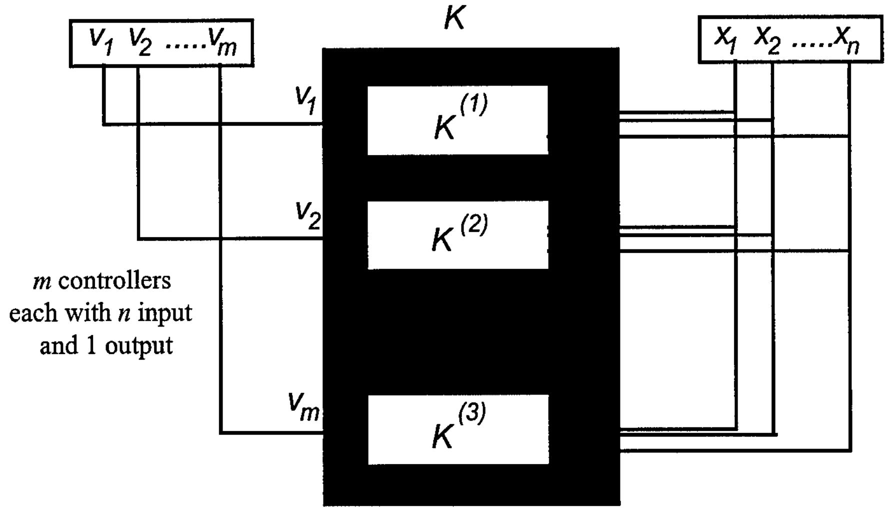
For implementation of fuzzy controllers LAMII has adopted a methodology based on the principle of modal equivalence. According to this principle the rule base for a fuzzy controller must be determined such that it provides identical results as those provided by a known controller for a particular input called modal values (these are uniformly distributed input values). Initially developed for a fuzzy implementation of classic linear controllers (PI, PID), subsequently this principle has been applied to different types of controllers.

Several applications of this principle have been developed: In collaboration with ELF a fuzzy controller for the regularization of the floating level in an oil refinery. The modal equivalence principle is exploited by initializing the fuzzy controller starting from a conventional existing linear controller, which had a good performance under normal conditions, but which was incapable of dealing with perturbation in these conditions. The fuzzy controller has then been modified locally by taking into account expert knowledge suitable to the current context of functioning.

The principle of modal equivalence has been tested in the synthesis of state feedback controllers. For example, suppose that one tries to implement as a fuzzy controller the system of equations v = Kx, under the assumption that the state vector is observable. For SISO processes the automatic synthesis of the fuzzy controller poses no difficulties. However, in the case of MIMO a decomposition is necessary such that a fuzzy controller can be associated to each output variable. In Fig. 4.6 the difference between the linear controller and the equivalent fuzzy controller for each output.



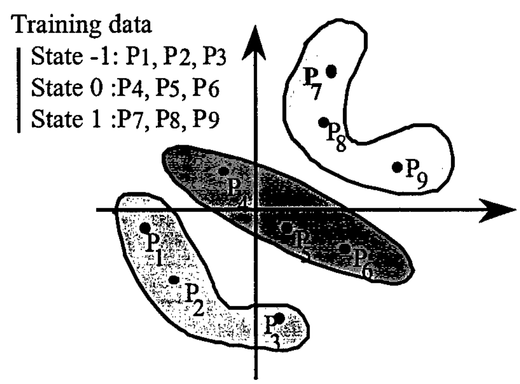
(a)



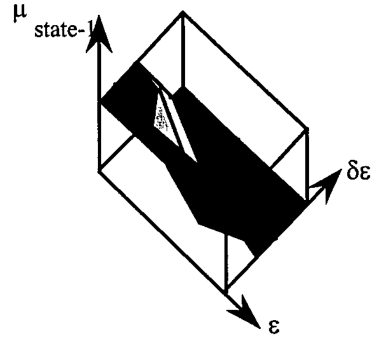
(b)

Figure 4.6: State feedback control

Finally the use of a fuzzy sensor can be used to give learning capability to a fuzzy controller (Fig. 7). The input values for which the output of the fuzzy controller corresponds to the output of a classic controller, or of a human operator, are aggregated and described by the fuzzy sensor linguistically in terms of the corresponding state. This method allows the treatment of modal values when these are not uniformly distributed in the input space, and provides a simple way of generating nonlinear control surfaces.



(a)



(b)

Figure 4.7: Training data and the fuzzy set describing the meaning of a state

Conclusion

The fuzzy logic work done at LAMII is of relatively recent origin - L. Foulloy has taken charge of the laboratory approximately five years ago. This work departs from the previous approaches to fuzzy logic in signal processing in that it actually implements a symbolic sensor (using fuzzy sets), providing thus the sensing results much closer to the way people describe them.

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5. Management of Uncertainty in Image Processing
Department Images
Ecole Nationale Superieure des Telecommunications (ENST)
Paris, France

General Information

The Image Department has been established in 1987 following a restructuring within ENST. Its origin is the Image and Video Groups from ENST, and several researchers from the departments of Electronics and Physics. Since 1987 the department has seen little change, except the normal move of personnel, at the rate of one to four a year - either receiving visiting researchers/teaching staff, or allowing leaves of its own staff.

Its main mission is instruction at all levels (including graduate and postgraduate) in the field of visual information processing. It consists of three groups, as follows:

Henri Maitre (Director)

A. Maruani (Assistant Director)

The group VIDEO(G. Balestrat, Engineer):

- four teaching staff (engineering degrees)
- one Ph. D. student
- 14 training

The group IMAGE(F. Schmidt, Ph. D. Engineer):

- nine teaching-research staff
- two CNRS researchers
- three Ph D students
- two training stage
- one visiting professor
- one post doctoral position

The group PIAO (Physics of the Image and Architecture for Optics), led by A.Maruani, Docteur-es-Science:

- nine teaching-research staff

- two CNRS researchers

- nineteen Ph. D. students (five of whom are from outside ENST)

- 21 training stage.

The research carried out follows three directions:

- image processing

- object processing

- high level image interpretation

Fuzzy methods for Image Processing and Image Understanding in the Departement Images at ENST

One of the most interesting works on fuzzy logic and applications is carried out in the Image Department of the National Superieure School of Telecommunications in Paris, France by Dr. Isabelle Bloch (maitre de conference) and Professor Henri Maitre, head of the department.

This work falls generally under the heading of data fusion, a technique very much needed and employed in image processing and understanding. To be noted is the fact that Dr. Bloch and her students have devoted a great deal of effort to identifying the correspondence between tools and problems to be solved. This means that fuzzy methods are adopted very much under the knowledge that they are most suitable for the problems considered.

The origin of the fuzzy approach here is in the work to extend concepts of the mathematical morphology by incorporating fuzzy concepts, Bloch and Maitre being the first to have done it. Mathematical morphology, notably its applications to image has its roots in France. It is based on defining various operators (dilation, contraction, etc.) in the neighborhood of pixels, in order to extract meaningful image characteristics.

In what follows we describe very briefly the work carried out by Dr. Bloch, as revealed by interviews with her and from the annual report of the department (in French).

The topics covered include:

o Comparison of different theories of data fusion

- o Evaluation of decision theories form the standpoint of their applicability to sensor fusion for processing satellite images
- o The role of Dempster-Shafer theory in image processing
- o Fuzzy mathematical morphology

We review each briefly:

Comparison of different theories of data fusion

In addressing the problem of comparing different theories for data fusion it is noted that, regardless of their characteristics these theories differ at the three distinct levels which constitute the process of fusion:

- o modeling of confidence functions
- o combination of confidence function
- o final decision

The theories under comparison in Bloch's study are probability, fuzzy sets and possibility, and Dempster-Shafer. Unusual for quantitative theories the comparison is done based on the axioms on which each of these theories rests.

Comparing probability methods and Dempster-Shafer approach, the following conclusion were drawn:

In the modeling stage the probability based methods are strongly constrained by functional relations while a Dempster-Shafer approach allows a much more flexible adaptation (for instance to cases where the sensors give information of the union of two classes without differentiating between them)

With respect to the combination of confidence the corresponding axioms entail the Bayes rule and Dempster-Shafer rule respectively.

In the last stage, that of decision the differences arise from the comparison of confidence degrees, allowing various types of decision in the Dempster-Shafer theory.

Evaluation of decision theories form the standpoint of their applicability to sensor fusion for processing satellite images

Interest in the study of satellite imaging has increased dramatically. In particular, sensor fusion has become a domain of intense activity due to the proliferation of satellites and on board sensors.

Bloch's team has embarqued on a comparative study of different techniques for sensor fusion, in order to determine their suitability, their capability to model the complex image content, and with the view of introducing them in all stages of fusion.

Bayesian inference and fuzzy sets based approaches are being compared in this study.

With respect to the Bayesain approach the following problems have been considered:

estimation of the prior probability distributions using an unsupervised method: results using images from the satellites SPOT and Landsat have confirmed the hypothesis of independence when the number of sensors increases;

determination of a criterion for deciding the quality of an image with respect to a class, using Fisher's interclass inertia: images can be ordered accordingly, and "bad" images can be discarded.

Fuzzy sets methods constitute a class of tools more flexible and with less constraints on the combining measures.

The results in this area include a method of learning membership functions as a function of estimation errors for parameters of conditional probabilities. The resulting class membership is coherent with the notion of membership to a fuzzy set and it is robust with respect to changes in the training areas and scenes.

The fuzzy fusion has been the object of two research directions:

(i) selection of combination operators, and

(ii) characterization of a combination operation as the force of the combination on the degrees of membership in a class of operators (conjunctive, disjunctive, hybrid and compensatory operators).

The role of Dempster-Shafer theory in image processing

Another alternative to the traditional probability and Bayesian methods used in image processing is the theory of Dempster-Shafer for evidence combination. Although used to some extent in satellite imaging, this theory has been very little used in medical imaging. The type of data, iconic rather than propositional, specific to the image domain have not been considered at all in the context of this theory. Bloch has considered its application for classification problems of multi-echo MRI images of ALD (adrenoleucodystrophie). Within the Dempster-Shafer theory, uncertainty, imprecision and ignorance (total, or global) can be represented at the time, and a large number of situation can be modelled. Modeling in D-S means estimating the mass functions, which then are combined to calculate belief and plausibility measures.

The method developed by Bloch has the following characteristics:

o in the modeling stage mass assignments are made to composed hypotheses (union of several classes) in order to represent the inability to differentiate between these in one image alone. This in itself is an improvement on the existing techniques.

o it was shown that even a rough estimate of these is sufficient and robust for the applications considered, as illustrated in Figure Bloch 1 showing the results for three classes, brain, cephalo-rahidian liquid, and pathology.

Fuzzy mathematical morphology

After the initial fuzzy extensions, in which fuzzy operators were introduced, Bloch has been led to consider new concepts of fuzzy distances. Characteristic of Bloch's work is her attention to what has been previously done, its suitability and classification of existing methods. Thus, in connection with fuzzy distances, which have been studied quite assiduously Bloch has grouped them according to the type of information required and according to their applicability to image processing, as follows:

(i) distances based on comparison of the membership functions only. These methods use functional and set theory methods taking as departure point information theory and or pattern recognition methods.

(ii) distances between fuzzy sets based on the distance d_E on the space E on which the fuzzy sets are defined. These are related to Euclidian distances, and are independent of the of the degrees of memberships of points in E to the respective fuzzy sets. Within this category fall the geometric methods and graph theory methods. Bloch has proposed a morphologic approach.

With respect to their use for image processing tasks, definitions in the first category should be limited to the case where the fuzzy sets to be compared represent the same structure, or a structure obtained from a an image and a model. These are pattern recognition applications based on models or analogies.

By contrast the definitions of the second category are much richer and allow an analysis of structures and objects from an image in a way which is more general, more complete and closer to the image specific application. They are thus much more promising as soon as spatial and topological information is important (as it is in the case of segmentation, classification and scene interpretation).

Distance of a point to a fuzzy set: Bloch has also considered the interesting but little studied elsewhere problem of a distance of a point in the universal set E to a fuzzy set defined on E, by a membership function m. Yet, this problem appears as being very important in image processing (e.g. mathematical morphology). In this case the distance on E, d_E appears to be important as well. Bloch has proposed two approaches to the distance of a point to a fuzzy set:

o first approach is based on the fuzzy morphology introduced in her previous work;

o the second involves defining a fuzzy distance (which is not a scalar) starting from the fuzzy dilatation.

Finally, a third and very novel (November 1995) topic addresses the problem of distances between two points of the same fuzzy set. This type of distance is widely used in the classical methods of image processing and pattern recognition and it is expected that their fuzzy equivalents will contribute to devising new concepts and tools for image processing when the imprecision of the image structures must be taken into account. The new concept is an adaptation of the concept of geodesic distance in a classical set by introducing the notion of fuzzy connectivity. The treatment is axiomatic, that is a number of axioms are imposed on the distance d_μ, between two points in the fuzzy set defined by the membership function μ. In addition to the usual distance axioms (taking nonnegative values, symmetry, separability, triangle inequality), additional axioms involving the membership function and the connectivity are set:

o $d\mu$ must depend on the shortest path between x and y which "exits the least" the fuzzy set , and it becomes infinitely large if it is impossible to go from x to y without passing through a point of degree 0;

o $d\mu$ is decreasing with $\mu(x)$ and $\mu(y)$;

dm is decreasing with respect to cm (where cm is the fuzzy connectivity defined as $c_\mu(x, y) = \max\{ \min [\mu(xi); 1<i<n]; L(x, y)\}$, where $L(x, y) = x=x1,...,xn=y$ is a path connecting x and y.

dm becomes the classical geodesic distance when μ is the indicator function of a crisp set.

Several candidates for this distance have been proposed and ranked according to how the axioms required are in fact satisfied. Initial results on this subject have been presented at the recent LFA'95 meeting in Paris (November 27-28), a national conference on fuzzy logic.

Applications of the geodesic fuzzy distance concept

mobile robots: in path planning for an autonomous mobile robot, the task of getting the robot on the shortest path between a start and goal positions based on a geodesic approach calls for computing the set X complementary of the set of obstacles in the environment E, and plan the path in X such that the robot passes as close as possible to obstacles. This solution is usually very fragile, as due to noise and imprecision error accumulations the robot may in fact end up "brushing" against obstacles. In an alternative approach, the attitude changes, requiring the robot to travel as far as possible from an obstacle. The fuzzy geodesic distance is then very effective: it suffices to construct a fuzzy set, whose membership function corresponds to degrees of passage safety. Such a fuzzy set can be constructed from a map of distances between objects and/or a cost function associated to the fragility of an object. Then

the best (in terms of safety) and fastest (shortest) path is then given by the fuzzy geodesic distance, for this path "exits the least" the fuzzy set, thus avoiding exactly those areas of low safety degrees.

medical application: In the domain of computer assisted surgery, the construction of a fuzzy set representing the "areas of least risk" allow the surgeon to prepare the surgery by finding the best path of intervention while remaining in these areas. For example, blood vessels would be assigned very low degrees to this fuzzy set. The results obtained using the fuzzy geodesic distance assure the shortest (and hence least tissue damaging) as well as the safest path of intervention.

Conclusion

This section gives but a very brief introduction to, and overview of the work on image treatment carried out within the Image Department of the Ecole National Superieure des telecommunications from Paris, France. It concentrated on the work using fuzzy sets, and other theories for modeling uncertainty and imprecision pervasive to the task of image processing, understanding, etc. For those interested in more details concerning this work a bibliography of related work, as well as contact point/person information are included below. Both from the standpoint of breadth or depth, the work done in this department is outstanding.

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6. Thomson CFS Central Research Laboratory France

General Information

Thomson CFS Central Research Laboratory is situated a short train ride South of Paris. It contains four functional services and ten research groups. I visited the Reasoning Laboratory (led by Remi Lissajoux) which is part of the group "Informatique et Cognition" (Computer Science and Cognition).

The objectives of this laboratory are to offer decision and concept support for other branches of Thomson in the area of computer based reasoning systems. The prevalent view is that to attain these objectives a one must think in terms of partnership between the computer/machine and its user. The application domains considered are in the area of control and command (with applications civil and military), supervision, robotics, diagnostic.

Difficulty: representation, acquisition and manipulation of large sets of data from two viewpoints: cognitive and computational

How to achieve: pure computer science/hard AI approach: developing programming languages. This entails the development, adaptation and deployment of computing technologies which support conceptual models for reasoning.

Thus, at the same time Fundamental Computing and AI.

Constraints Logic Programming (CLP)

A substantial effort is dedicated to Constraints Logic Programming (CLP). This is viewed as technology within AI and not only an optimization method, which allows the separation of declaration of knowledge, resolution and algorithms. Figure 6.1 shows the evolution of the work in this area within the reasoning laboratory.

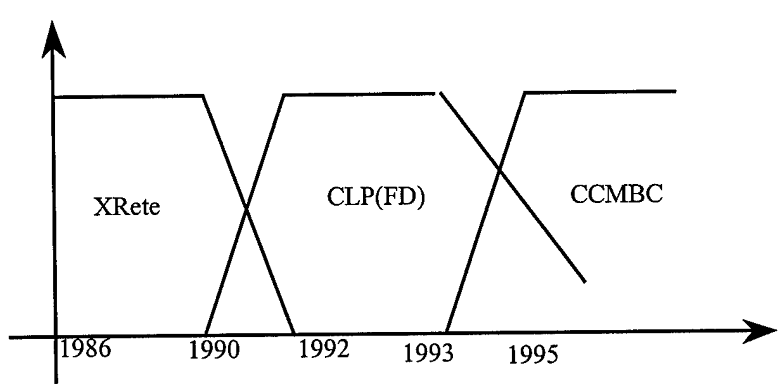


Figure 6.1: Evolution of CLP work within the "Constraints" group

In spite of sustained research work in this area, with several interesting general results a 1994 report on the group "Constraints" reached the conclusion that, with a few exceptions, the constraints technology has not been adopted at Thomson-CFS.

Several domains of application have been identified: sensor configuration, missile deployment, missiles planning, resource management, logistics, task scheduling. In general there have been several small projects with limited success.

The conclusion from these is that brute force CLP is of little use to the Thomson-CFS units.

Distributed planning: concurrent languages with constraints for multi-user planning (Fig. 6.2)

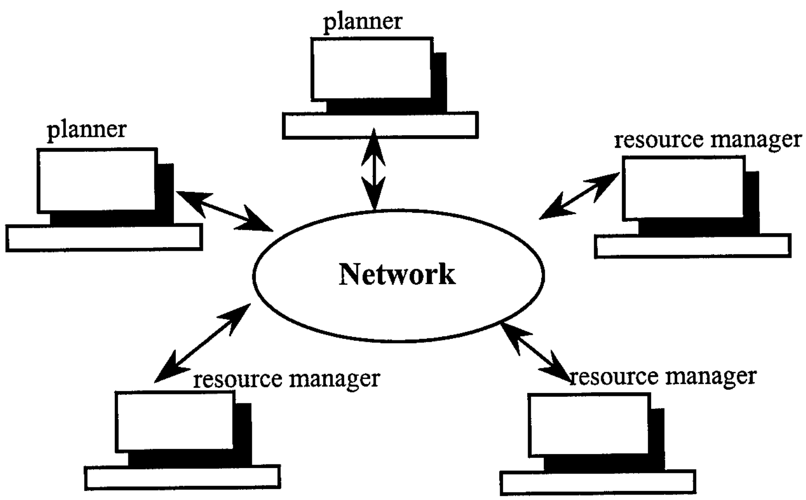


Figure 6.2 Concept of distributed planning

This work has as goal the realization of systems which allow distant agents to schedule tasks which use shared resources (Figure 6.2). The problem here is one of coordination. Applications include distributed databases, and multi agent planning. The approach has been to develop a distributed version of the constraint logic programming; to validate the technology on real problems making use of distributed artificial intelligence, distributed data bases, reactive CLP, optimization. The language DMeta(F) (Figure 6.3) has been developed for this purpose.

DMeta(X)	**Distributed databases**	distributed extensions
Meta(X)	**X= finite domains** **X= Booleans**	sequential CLP

Figure 6.3 CLP languages

Implementation is independent on the constraints algebra used; the base is a classic CLP base which can be extended with other layers; integration with reactive CLP.

Task scheduling: the simpler version is for signal processing software; architecture; programs

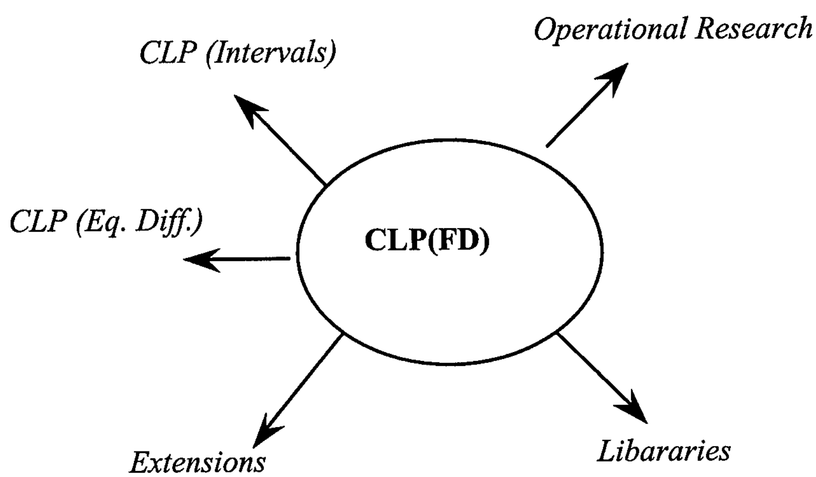
higher level support in computer configuration.

Reactive CLP: aims at realizing systems which can react at external events.

CCMBC (J. Jourdan) presents a methodology for modeling complex systems in CLP. The basic concept is that of *concurrent logic models,* which calls for decomposing a problem in interdependent sub-problems.

The testing is done on a task scheduling problem. Currently under use for a traffic flow management.

CCMBC makes possible: hierarchical reasoning, compilation of CLP programs, modularity, coupling of rules and constraints.



The "constraints" group posses a unique expertise in the basic technology and the methodology of CLP. This is a domain largely unexplored both from theoretical and application point of view. Thus this group finds itself in a unique position to develop this new technology. In particular, in the framework of annotated logic, it can contribute to methods for management of uncertainty, conflict resolution, and temporal and hypothetical reasoning.

Incremental algorithms: use of CLP in the framework of anytime algorithms - algorithms which can be interrupted at any moment and yielding a result. Use in this context of the constraints propagation algorithms from CLP.

Fuzzy logic work

Currently this group is exploring collaboration with INRETS in applying a CLP approach management of transport flotillas, mission logistic. However, during our discussions it became apparent for these and

other applications there appears to be a need for a concept of **soft constraints, for which a fuzzy logic based approach could be used.**

Thomson's work on fuzzy logic is represented by one man only, Dr. Michel Grabisch, who works in the Reasoning laboratory as well. In what seemed very unusual move the research on neural networks has been discontinued and at the time of my visit hopes were expressed that Grabisch would be able to compensate for that with his research on fuzzy logic.

This research concerns the broad area of evidence aggregation based on non additive measures. In a narrower sense this research is in the area of fuzzy and Choquet integrals. These are defined with respect to a non-additive set measure, which in fuzzy logic is known under the name of fuzzy measure. Grabisch has done important work on the mathematical theory of these integrals, and has investigated some applications. These as well as a survey of other applications in different countries are presented in his most recent papers, some of which are included in the bibliography below.

Grabisch has also developed a computer program for pattern classification using the fuzzy integral, and comparison with other statistical methods (such as the Parzen classifiers).

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7. Intelligent methods for traffic management at the National Institute for Transports and their Security (INRETS) Arcueil, France

General information

INRETS was created in September 1985 from the teams of the Institute for Research of Transport (IRT), and the National Organism for Road Safety (ONSER). Since its inception INRETS has contributed to research in the area of traffic management and traffic security both on national and international levels (within and outside the European Union).

INRETS proclaims to have three "grand missions":

- o accomplish, facilitate and evaluate research and technological development dedicated to the improvement of means of transportation and traffic;
- o supply expertise and advice in these areas both at the technical as well as social and economic levels;
- o disseminate or facilitate the dissemination of scientific results

...and three principles of action to achieve these missions:

- o an interdisciplinary approach to all problems related to transport
- o a comprehensive approach to all types of transport;
- o achieve a balance between fundamental and applied research

INRETS has a personnel of approximately 400 of which 180 researchers, 130 technical support staff, the remaining making up the administrative component.

It comprises 13 research units located in four locations in France: Arcueil, Bron, Lille and Salon-de-Provence, Marseille.

The research objectives are determined on a multi-annual basis and cover the domains of

- o organization/control of transports
- o transport exploitation,
- o transport security
- o transport technology
- o protection of the environment and
- o ergonomics

It collaborates with various users and industries via 7 specialized user committees.

National and international collaborations

...with the University of Lille and University of Valenciennes on guided transports, industrial rail transports, improvement of the ground-vehicle transmission, obstacle detection, localization and speed estimation;

..with these universities and University of Kent and Brussels University and Louvain University it collaborates on economic impact of the creation and exploitation of the link under the English Channel;

...with University of Aix-Marseile II, where it has created the Laboratory of Applied Biomechanics (LBA) of the School of Medicine, on the North Sector of Marseille;

...with the National Society for Railways (SNCF) and The Rapid Area Transportation System (including the Metropolitan Underground in Paris), with automotive industry (PSA, Michelin, etc.)

Internationally it collaborates with

o Transportation Research Board (USA)

o European Foundation of Sciences - working group for the development of computer based applications for transport

o REDES: the network of urban transport in Latin America

o IRCOBI: International Association of research on secondary security on impact biomechanics;

o WHO: World Health Organization;

International Projects

o French-German project Artemis on the command and control of train systems; link between the French project ASTREE and the German project DIANE; modeling of supply and demand for rapid rail systems

o EUREKA: Participation to the project PROMETEUS on the intelligent vehicle, capable of dialog with other vehicles; evaluation of driving aids;

o European Community Experimental vehicle: Collaborate on establishing the test conditions for vehicles in lateral shock; security of heavy transports; evaluation of pedestrian protection systems (in cooperation with TRRL in UK, TNO in Netherlands, BAST in Germany)

Result

In transport organization:

- o modeling the demand on long distance transports;
- o Channel tunnel: work on security and traffic flow evaluation
- o modeling of demand for transport in urban areas;
- o large urban projects: LASER for the city of Paris; Schema for the Greater Parisian Urban area
- o modeling of traffic on complex road networks;
- o short term traffic forecasting;

Results in exploitation of transports

Improvement of the sensor-management, data-command for guided and automobile traffic:

- o automatic image processing (patent with Ecole des Mines);

Command:

- o Software for road access on the South Paris beltway (ALINEA);
- o Expert system, SAIGE: traffic jam management (experimentally implemented in the center of Paris);
- o IAGO system for ground-vehicle transmission and localization;
- o Image processing based detection of intrusions on train lines;

Traffic regulation - urban and highway systems:

- o Software SIRTAKI: highway system in the ile de France;
- o Software ASTER: statistical analysis for exploitation and regulation of urban networks;
- o Software CAMEL: for public lines of transport;

Artificial Intelligence techniques for supervision and control of intersections with traffic regulated by stop lights

- o databases: it has created extensive databases on accidents, urban mobility, supply and demand in passenger transport
- o software LASCAR (in cooperation with University Lyon II) for tracking cost of street restructuring;

Results in transport security

Expertise for the safety committees for:

- o the system SACEM (line A of the RER)
- o Val de Lille, Lyon 1 and 1bis

o Line D of the Lyon subway system

o certification of the system POMA 2000 in Laon

o ORLYVAL

etc.

Research on safety devices:

o concept and validation of security software for guided transport;

o device anti maritime collisions to reduce such accidents in the English Channel;

o road safety (for the ministry of transport):

o knowledge on the human behavior regarding:

o national program for car driving training and for the driver's licence "with points"

o the relation alcohol-road accidents

o analysis of speeding behavior

o experiments with emergency manoeuvres on the simulator from Daimler-Benz;

Knowledge of risks:

o software for risk evaluation in the transport of hazardous materials;

o global safety study in the Loire and Eure region;

o analysis of accidents involving two wheels vehicles

vehicles:

o functional evaluation of driving aids;

o study on the vigilance in driving, in real driving conditions;

o accidentology and shock prevention and protection

o study of the antiblock system (in cooperation with Michelin)

o improvement of the primary security

o isolation of narrow obstacles with shock absorbers (patent with SODIREL Co.);

etc.

Arcueil center

The Arcueil Center comprises the following groups/laboratories:

o Research Center in Informatics (Computer Science)

o Laboratory for Image synthesis

o Simulation

o Department of Traffic Regulation and Analysis

o Department of for Evaluation and research in Accidentology

o Department of the Economic and Social Aspects of Transports

o Laboratory of driving psychology

o Laboratory of New technologies

- o **Department of Applied Mathematics and Artificial Intelligence (MAIA)** - whose activities are presented in this section

An interesting point, in connection with the traffic management systems developed by the French is that these are being successfully exported in other countries, including United Kingdom and Germany. In this respect there seems to be a reverse of the state of things, which would have the French more preoccupied by theories, rather than products. When queried about this aspect, one learns that in the United Kingdom there is a great deal of theory about traffic flow, traffic management, while the actual systems are imported. One reason for this could be the fact that the British have been forced to think about traffic problems from the very early on at the beginning of industrial revolution. However, technology available at the time did not permit more than rudimentary traffic management techniques (usually by introduction of safety rules, and road signs); theory however was free to develop at the same time impulsionated by strong scientific research in general. By the same token, the French seem to have ignored the traffic problems as long as possible, aided in this by the fact that there were no major land/space problems. Faced, much more recently with such problems, they could, at least in principle, enlist the assistance from computer based technology and presently implementing it in actual system.

AI Based Supervisor for Traffic Control (CLAIRE)

CLAIRE is a context-free supervisor for traffic control based on AI techniques. It uses an adaptive systems like paradigm, ideas from congestion management; it takes into account the role of operators and system-driver communication.

A cooperation between intelligent methods (AI) and automatic approach is the basis for the CLAIRE system; the intelligent component is assigned the task of high level supervision; the automatic approach is assigned the task of conventional control, under normal conditions of operation (Fig. 7.1).

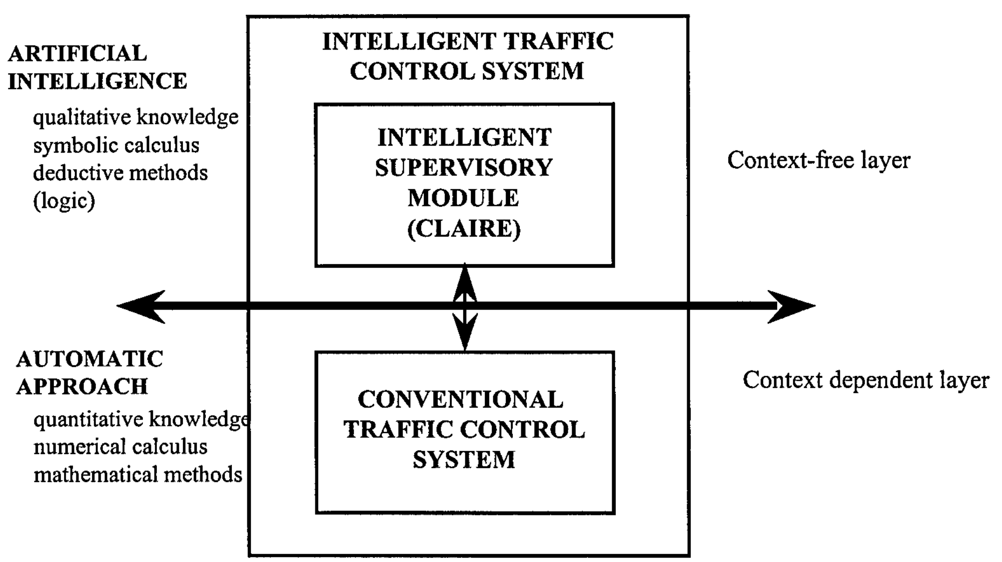

Fig. 7.1 Basic concept of CLAIRE

In addition CLAIRE is a tool for the human operator and it offers:

o improved relationship between man and the real world (diagnosis, explanation of phenomena, support to actions);

o improved relationship between man and machine (e.g. understanding the results of the automatic system)

o improved relationship between the machine and the real world.

In fact. CLAIRE proposes a new paradigm for traffic control,. which necessitates intelligent techniques and seeks to optimize the three way relationship between man, machine and the real world. (Figure 7.2) In the new paradigm the real world provides input to the system (through sensors), which are then interpreted, using both models and human operator knowledge, to produce actions to be applied on the real world.

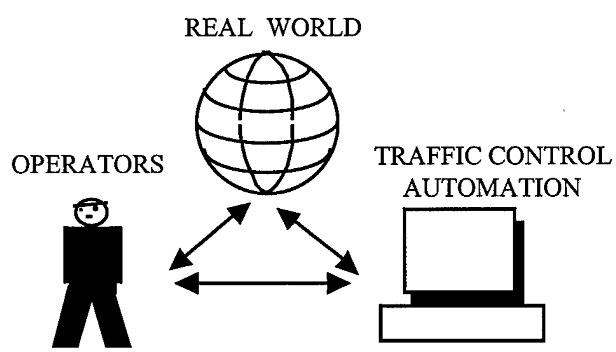

Figure 7.2 New paradigm for intelligent traffic management

CLAIRE contains several modules depicted in Figure 7.3 and whose goals are shown in Table 7.1.

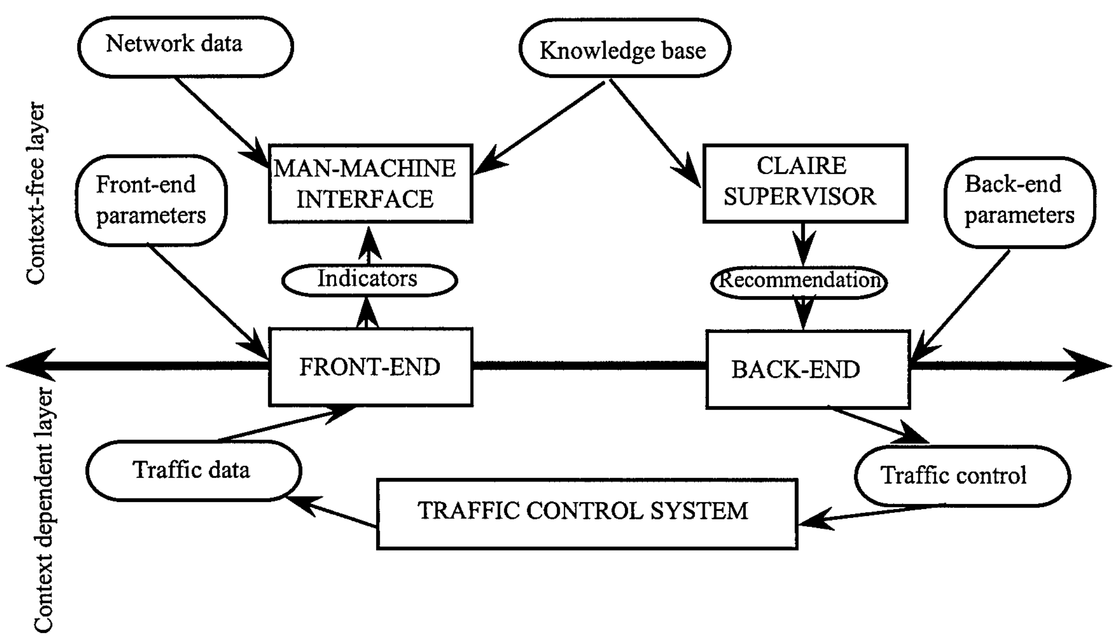

Figure 7.3 Components of CLAIRE

Table 7.1 Functions of CLAIRE modules

module	goal
front-end	conversion of traffic data (volume, occupancy rate, etc.) into qualitative states
expert modules	interpretation of the data in the light of its knowledge about the network and past cases
back-end module	conversion of strategic recommendations into real control system commands
off-line expert modules	analysis of congestion patterns and development of congestion actions

CLAIRE functions

There are six main functions (Figure 7.4). They are grouped into two subsystems. The first of these, intervenes at the operation level, and it groups the functions of front-end for perception, congestion monitoring for diagnostic, congestion control and back-end for control. This subsystem assumes part of a human operator's work, by implementing well established procedures. This subsystem forms the core of SAGE a system which preceded CLAIRE. In fact, it was from SAGE's exploitation that it became clear of the need of the additional functions included in CLAIRE.

The second subsystem runs off-line, and includes the functions of congestion recognition, and learning. It operates at a strategic level Its "work" is similar to that of traffic engineers: analysis of phenomena, development of new congestion control strategies.

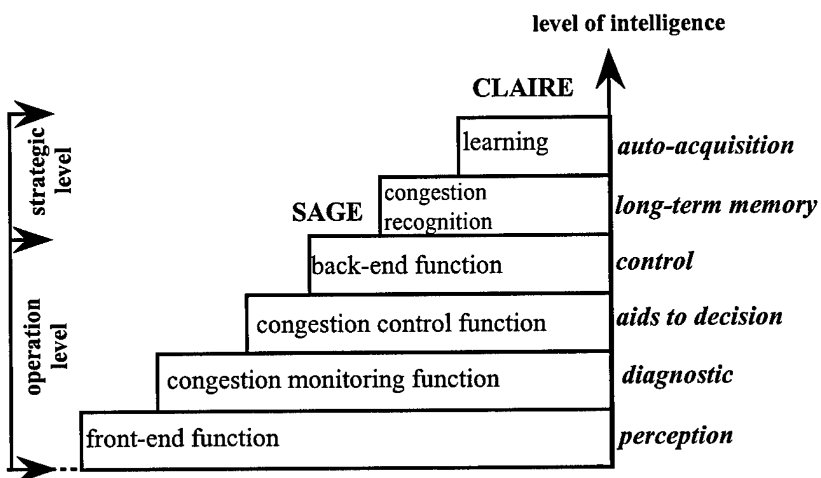

Figure 7.4 CLAIRE functions

The intelligent traffic junction management system

This work, carried out as part of the European DRIVE program (the INVAID project), concerns the integration of various technologies, Artificial Intelligence and Computer Vision, for traffic management (monitoring and control) at intersection of urban road networks.

The work is being experimented with in a real situation, at the intersection in front of INRETS location in Arcueil, France. Other sites include Lyon, and Valencia in Spain (in collaboration with a Spanish partner LISITT).

The system has four main components:

- o monitoring subsystem
- o control subsystem
- o communication subsystem
- o simulation subsystem

Initial experiments concerned:

- o validation of the modeling functions
- o adaptation of the generic models to specific sites,
- o adaptation of the outputs of the systems to traffic engineers queries and problems,
- o validation of measurements used in the system to detect incidents
- o integration of the system into existing installations and assessment of its functioning.

Other experiments involve monitoring a network of intersections. The system's functional architecture is shown in Figure 7.5.

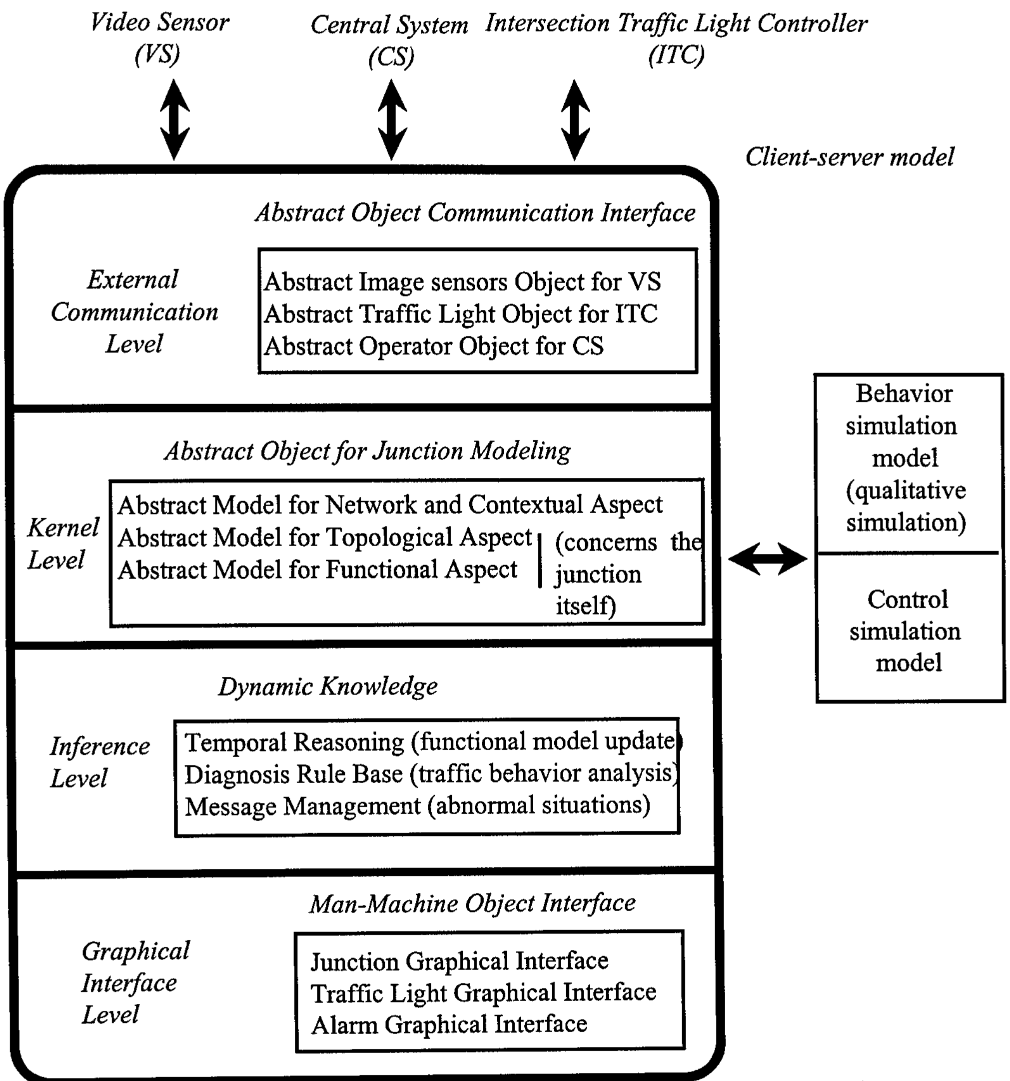

Figure 7.5 Concept for the intelligent traffic junction management system

The heart of the system is a Real-Time-Knowledge-Based System and a simulation system. Characteristic to the Real-Time-Knowledge-Based System is its carrying out mechanism, which allows communication with nearby junctions (exchange of local information), vehicles (in view of intelligent guidance), intersection controller, video sensors and with the central Control System (in view of global traffic management).

Experimental Results

Several experiments were carried out, in Paris (France) and Valencia (Spain), in the framework of DRIVE I program (project V1026-INVAID: integration of Vision Techniques for Automatic Incident detection).

Currently, in the framework of DRIVE II, LLAMD (Lyon, London, Amsterdam, Munich, Dublin) pilot program it is attempted to integrate into the other functions of the system the Bus Priority system.

In Valencia six junctions are fitted with the necessary equipment (one to three cameras per junction) to perform experiments. Each camera is analyzed by a Local Sensor Module which provides traffic measurements. To each junction is associated a Computer Vision Intersection Module(CVIM) which detects incidents occurring within the visual field of the camera. CVIM must make a comprehensive diagnosis of the current junction situation. CVIM requires information from LSM and the traffic light status from Traffic Light Module (TLM) The output of each CVIM is then passed on to the Central Control Room of the Valencia, to the Central System which is in charge of supervising the whole network.

In Lyon experiments aim to manage traffic such that (i) buses are given priority and (ii) incidents which can disturb the traffic are detected. The initial focus is on a an AID (Automatic Incident detection) system for bus routes.

Traffic management for automatic subway lines

This problem is part of a PhD thesis done by R. Hartany of LAFORIA in conjunction with INRETS. The approach is to treat this in the frameowrk of neuro-fuzzy systems. More precisely the traffic manegemt system is a fuzzy system, which in turn is learned with neural network approach (Figure 7.6).

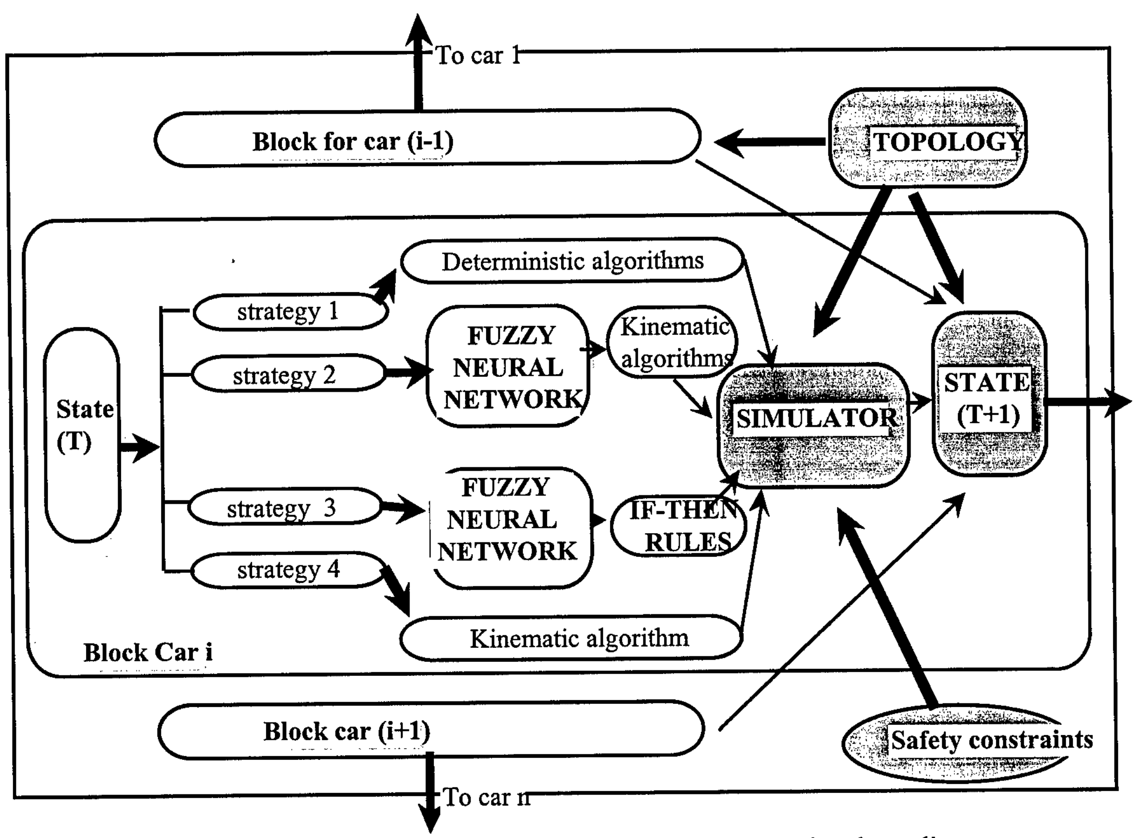

Figure 7.6 Ouline of the fuzzy system for control of automatic subway lines

Different strategies are opted for at different stages of the management. They are either in the form of a body of fuzzy rules or, they corespond to kinematic algorithms. For example, Strategy 1 concerns the

management of traffic between stops; Strategy 2 takes into account temporal data at the exit from a station, and uses it during the acceleration stage. A fuzzy neuro system (SIFANE) with three inputs (delay of the three cars of the system) and one output (desired variation of this delay) is used for a temporal control.

An example of fuzzy rule for this strategy is as follows:

IF

the car_position corresponds to Strategy 2 and

the delay of car i-1 is BIG and the delay of car i is MEDIUM

THEN

increase of the delay of car i is MEDIUM.

An interpreter is used to implement each strategy. For Strategy 2 this interpreter acts as follows: based on the results obtained from the fuzzy rules defining the strategy a kinematics algorithm allows to determine the proper acceleration.

Further details of this work are found in Hartani's thesis (in French). Experiments with the system deisgend here have been carried out with line 1 of the VAL[23] system in the City of Lille.

Conclusion

This section presented work on traffic management systems done at INRETS Paris, France. Two of the projects presented use AI techniques, while the last project uses fuzzy and neural techniques. Although this report is to focus on the last type of projects the first two were included for the following reason: each presented a very important traffic management problem, with strong implications for the current effort on the intelligent traffic maintenance systems.

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[23]VAL stands for Vehicula Automatique Leger (light Automaic vehicle).

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8. FRIL - Fuzzy Relational Inference Language
Fuzzy Logic Research at Bristol University, Department of Engineering Mathematics

One of the pioneers in research in fuzzy logic is James F. Baldwin Professor at Bristol University. His work, from mid to late seventies has dealt with fuzzy control, at a time when very little (FLS Automation in Denmark, not whitstanding) was done in this area. His approach was relational based, that is control equations were represented as fuzzy relations. This is not the current and most successful scheme used today employing fuzzy IF-THEN rules. However, there is today a tendency to revisit this approach, especially for some of the more complex control problems.

Throughout the eighties, and presently, Baldwin and his group have focused away from fuzzy control,and more on more general theories of uncertainty, as required for intelligent systems. It must be noted that this is the only group in U.K. which does not focus on fuzzy control as the primary goal of their research. Of course, fuzzy control falls into one of the application categories.

FRIL - The Fuzzy Relational Inference Language

The most important contribution of Baldwin's work is the development of the language FRIL, built on his theory for Support Logic Programming. Currently FRIL is available as a commercial product, from FRIL Systems Ltd. (the best way to obtain information about FRIL is to contact J. Baldwin at his Bristol University address).

FRIL can be thought of as an extension of Prolog to handle uncertainty. However, this should not be viewed as a mere shell. It contains as a subset a proper prolog and also a support logic programming system. More over the two components are well integrated, such that a user can write programs in which prolog and support logic programming statements are present.

A support logic statement is of the form ((conclusion)(body)) :(($l_1 u_1$)(l_2 u_2))

where l_i u_i are number in [0, 1], with the meaning

l_1£ Pr(conclusion / body)£u_1

l_2£ Pr(conclusion / NOT body)£u_2

Support logic programming is built on the theory of mass assignments. In the framework of this theory, probabilistic, evidential and fuzzy reasoning can be represented and performed. Fuzzy sets are easily represented as well as rules involving fuzzy predicates. Table 8.1 shows the main types of rules ion FRIL and corresponding examples

Table 8.1 Examples of FRIL rules

rule type	example	comments

Prolog rules	((append () L L)) ((append (H1 |T1) L2 (H1|T))(append T1 L2 T))	recursive rule
Probabilistic/fuzzy rule	(*tall* {67:0, 72:1}) (*large* {10:0.7, 11:0.9, 12:1}) ((shoe_size of X is *large*) (height of X is *tall*)) : ((0.9 1)(0 0.3))	*large* and *tall* are fuzzy sets support pairs
Evidential logic rule	(1) ((book X is worth reading) (evlog most ((famous writer is author of X) 0.2 (keywords of text of X relevant) 0.2 (scan impression of X is ok) 0.3 *(reviews of X is good)* 0.1 *(extent of X suitable)* 0.05 (publication date of X recent) 0.1))): (0.9 1) (2) ((extent of X suitable) (conj (number of pages of X not too big) (page_ize of X is normal)) : ((1 1)(0 0))	(1) top rule (2) subsidiary rule
Causal relational rule	extends probabilistic rules	

The syntactic unification of prolog is replaced with a semantic unification, which allows fuzzy sets defining the same attribute (eg *tall* or *medium* for height) to be unified (matched).

Other features of FRIL include:

- o voting model based semantics for fuzzy sets
- o conversion between frequency distributions and fuzzy sets based on the notion of least prjudiced probability distribution

The latest work of Baldwin's group is on a Intelligent Fuzzy Data Browser, whose general diagram is shown in Figure 8.1. The fuzzy data browser is implemented in FRIL and it is now in a testing stage. Demonstrations of it at some meetings (eg EUFIT'95) have shown impressive initial results in its learning, and summarizing capabilities.

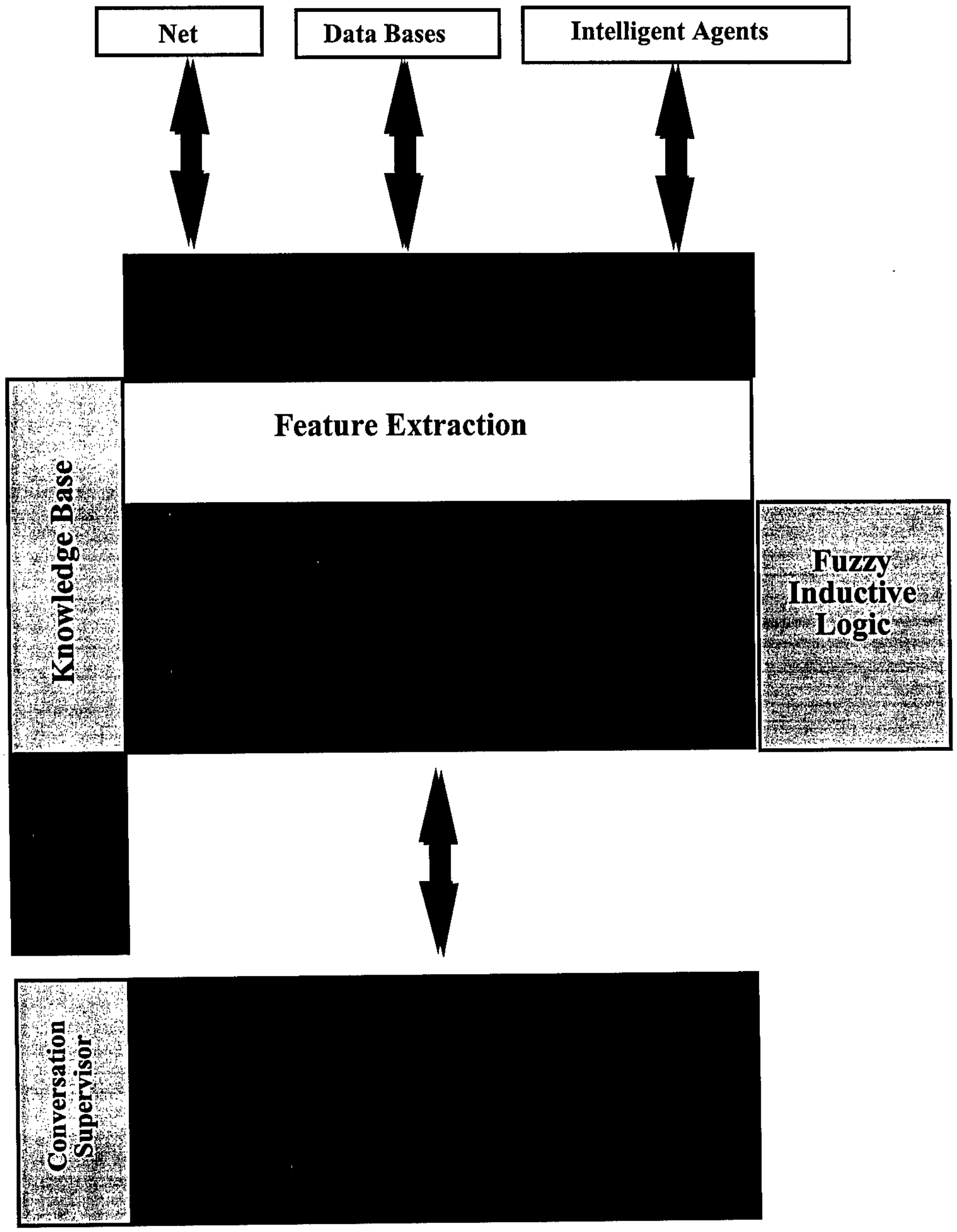

Fig. 8.1 Intelligent Fuzzy Data Browser

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9. Research on Fuzzy Constraints Satisfaction at Technical University of Vienna Institute for Information Systems Christian Doppler Laboratory for Expert Systems

General information

Background on Austrian Industries: This is a group of industries numbering more than 300 affiliates - making it the largest group in Austria and one of the 100 largest in Europe.

Research and Development in the Austrian Industries: The research and development work within this group is carried out on three levels:

The first level, concerns market-oriented and product-oriented research and development. Approximately three quarters of the amount spent for research and development of the Austrian Industries is invested at this level.

The second level concerns synergy projects and interdisciplinary research such as biotechnology, automation, and information technology, new material and laser technology. Approximately one fifth of the amount spent on research and development is invested at this level.

At the third level basic research done at CD-Laboratories aim at stimulating innovative aspects among the Austrian Industries affiliates. Two to three percent of the R&D funds are earmarked for this purpose.

Through CD-Laboratories the Austrian Industries affiliates have access to new scientific developments and technological knowledge. The CD Laboratories do basic research in areas of ongoing interest for Austrian Industries. These include material sciences, electrical engineering, process technique, physics, plastic chemistry, microelectronics, and information technology.

The Christian Doppler Laboratory for Expert Systems was founded in October 1989 under the leadership of Prof. Georg Gottlob. The original aim was to provide knowledge transfer in the domain of expert systems for the staff of Austrian Industries. At the same time research objectives are established as a function of individual projects with the affiliates of Austrian Industries.

In the first years two prototype systems have been developed, model-based diagnosis (MOMO) and interval based representation of time (TimEx). In addition a scheduling expert system for a high-grade steel plant has been developed in cooperation with the Viennese Alcatel-Elin Research Center. Currently two projects are in progress:

In a scheduling project for a second steel plant an existing tool is improved with relaxation techniques based on fuzzy logic and with a knowledge-based user interface. This project, in combination with the

experiences made in the high-grade steel plant are used to develop a model-based acquisition method for flow-shop scheduling applications.

The second project deals with diagnosis and preventive maintenance for steel industry. In this project model-based diagnosis is used.

Research topics at Christian Doppler Laboratory for Expert Systems

Integrated into the older and well established Institute for Information Science of the Technical University of Vienna, enabled the laboratory to achieve early and widespread recognition, testimony of which are the 108 papers published in international journals or presented at international meetings. The topics covered by these include:

- qualitative modeling
- temporal reasoning
- qualitative reasoning and simulation
- **knowledge-based scheduling**
- **fuzzy reasoning**
- representation for real-time applications
- model-based diagnosis and preventive maintenance
- knowledge-based acquisition of knowledge
- multi-agents
- logic-oriented databases
- object-oriented databases
- knowledge-based user interface
- hypertext and multimedia

In all these areas an important aspect of the basic research bears on the complexity of algorithms. The application domains are the steel industry (production and processing), plant construction, energy technology and flexible manufacturing.

Fuzzy Logic research is represented here in the work of Wolfgang Slany and some graduate students in his group. Slany himself has defended his PhD thesis Fuzzy Scheduling in 1994. Creative and very

dynamic Slany has been the main force behind the organization of the Austrian AI Conference dedicated to Fuzzy Logic in AI, in the Summer of 1993. His creativity is evident from his participation at international conferences and in the fact that he has succeeded, in short time and in spite of his youth, to organize a small group of graduate students working in fuzzy control.

The work on fuzzy logic has developed around that of scheduling (see the bibliography below). Below follows a description of this and related work.

FLIP++ A fuzzy logic inference processor library (M. Bonner, S. Mayer, A. Raggl, W. Slany). FLIP++ is a fuzzy logic inference processor library developed in C++ to do calculations with uncertain data and priorities. It operates on a hierarchy of rules. In this each rule is qualified by an importance factor. A rule may be expressed in terms of fuzzy condition and conclusion parts. Only those rules of the hierarchy which are needed for a particular result are evaluated. The result itself can be presented either as a list of membership values, or as a unique crisp value (as needed for fuzzy control). The library also contains the functionality needed to manage one or more sets of rules on all the data.

With the user interface InterFLIP++ library FLIP++ can be used as a standalone fuzzy control module. Alternatively, it can be linked with other applications in which manipulation of fuzzy sets is required.

FLIP++ as part of a scheduling project.

As part of the *FLIP++ library for real-world decision problems, FLIP++ allows for solving optimization problems under vague constraints qualified by importance degrees and using uncertain data. Compromise between conflicting data can be effectively modeled. Typical applications areas include: scheduling, design, configuration, planning, and classification. *FLIP++ is composed of the following layered sub-libraries:

- FLIP++: the basic fuzzy logic inference processor
- ConFLIP++: the static fuzzy constraints library
- DynaFLIP++: the dynamic fuzzy constraints library
- DomFLIP++: the domain knowledge representation library
- OptiFLIP++: the heuristic optimizing library; several such heuristics have been implemented and tested so far:
    - a min-conflicts repair based iterative deepening heuristic
    - a min-conflicts repair based random search hill climbing heuristic
    - a min-conflicts repair based genetic algorithm heuristic

- o CheckFLIP++: the knowledge-change consistency check library that also allows to fine-tune the configuration parameters of a problem
- o InterFLIP++: the user interface for all other libraries
- o DocuFLIP++: the on-line documentation available separately for end users, knowledge-engineers, and programmers. This is accessible via the World-Wide-Web as HTML document.

Knowledge representation in FLIP++.

Qualitative representation: To represent qualitative concepts (such as large, small etc.) FLIP++ use qualitative variables (in the usual fuzzy literature these are known as linguistic variables). This is illustrated by the following example of constraints needed for scheduling a steel making plant. In this three types of constraints are used, each of which consisting of several different constraints:

- o chemical compatibility constraints
- o temporal constraints (for representation of delivery dates)
- o capacity constraints (for human, machinery, etc.)

The chemical compatibility constraint has as sub-constraint the chemical compatibility for every measured chemical element. This in turn is represented using the percentage difference for the element as a qualitative variable taking on the values: *negative, negative_small, zero, positive-small, positive,* each of which is represented as a fuzzy set. The global compatibility constraint is then obtained by aggregating element constraints using rules.

Quantitative knowledge representation in FLIP++

Fuzzy set membership functions are used to describe quantitatively the meaning of the terms used as values for qualitative variables.

Relations between qualitative variables.

Fuzzy IF-THEN rules are used to express relations between various qualitative variables. The quantitative representation, i.e. the membership functions associated to terms defining a qualitative variable are used here to evaluate the condition part of a rule given data.

In addition each constraint takes values into a set of two elements: *satisfied, not-satisfied*, which can also be expressed as fuzzy sets.

Modularity - tree of constraints.

For ease of understanding and development, and in an effort to mirror the human problem solving approach, FLIP++ allows a modular construction of the system. The rule hierarchy can be built generated automatically via the implicit dependence between rules, or it can be built explicitly by building various smaller modules which are then linked. A module can be associated to each type of constraints. For example, in the steel making example, three modules, corresponding to the three different types of constraints an be built. A major contribution of FLIP++ is the ability to combine small sets of rules into a larger knowledge base. Another aspect was the implementation of an associative rule evaluation algorithm, such that the order in which the rules are evaluated is not important.

When modules are combined they are effectively linked by adding rules expressing the relations between modules. This is done in the same manner as combining qualitative variables. The only restriction in the size of a system that can be built with FLIP++ comes from the platform on which it runs.

Alternatively to compensate for this restrictions single modules can be evaluated. The connections between them are then expressed in a new module with new rules relating the output variables of the individual modules. In this case it is necessary to evaluate this module again each time changes are made into one of the lower modules.

Operators.

For the particular aims of FLIP++ the authors have pursued the design of operators closer to the human aggregation operators (at least for the type of problems considered). Such operators are the associative compensatory operators. In addition to associativity (desired for reasons explained above) the compensatory aspect is generally agreed to conform closer to the human reasoning. However, in general compensatory operators found in the literature are not associative. FLIP++ uses a class of operators initially defined by Klement[24] and others starting from a multiplicative generator function. More precisely, an associative compensatory operator is given by the following definition:

Let $f\colon[0,1]\to[0,+\infty]$ be a continuous, strictly increasing function with $f(0)=0$ and $f(1)=+\infty$

. Then a binary operation $C\colon[0,1]^2\to[0,1]$ defined by

$$C(x,y)=\begin{cases} f^{-1}(f(x)\cdot f(y)) & \mathit{if}\ \{x,y\}\neq\{0,1\} \\ 0 & \mathit{otherwise} \end{cases}$$

is called an associative compensatory operator. The generator function used in FLIP++ for the compensatory associative operator, denoted ACOtan, is $f(x)=\tan(\frac{\pi}{2}\cdot x)$.

Performance of FLIP++

[24]E. P. Klement, R. Mesiar, E. Pap. Associative compensatory operators. In Mario fedrizzi, E. P. Klement, A. Ventre, A. Zorat (edts.) Proceedings of CIFT'94: Current Issues in Fuzzy Technologies: Decision Models and Systems, Trento, Italy June 1994.

FLIP++ is still in course of development and optimization. However, initial performance results are never the less indicative. For testing purposes the chemical constraint was run for the steel making process. Three input variables for chemical percentage difference were created. The chemical compatibility constraints were derived using five relations for each connection. These constraints are aggregated to one overall constraint with two rules and the ACOtan operator was used for aggregation.

The overall constraint was evaluated 1,000 times. On a SUN Sparc station 1+ this took 17.9 seconds user time. However, taking into account the fact that in each run each single rule was evaluated for each variable, it follows that substantially improved performance can be obtained.

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Wolfgang Slany Fuzzy Scheduling PhD Thesis, Technical University of Vienna 1994 URL: ftp://mira.dbai.tuwien.ac.at/pub/slany/thesis.ps.z

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10. Fuzzy logic based signal processing at SGS-Thomson Microelectronics Milan, Italy

General Information

Situated close to Milan SGS-Thomson Microelectronics seemed to thrive. A French-Italian company, in which the official working language is English, SGS-Thomson is posed for further development: the place was teaming with activity during a visit there early September, and according to its employees who mentioned increased share prices. Ground was being broken for a new building and people seemed very busy at their own work.

The visit with the Corporate Advanced Systems Architecture group lasted about ten hours. The discussions concerned two topics: fuzzy systems in general, and fuzzy logic approaches for image/video processing and understanding as part of the more general problem of signal processing. The Corporate System Architecture Group has the task to investigate new techniques, paradigms which can be transferred to other departments within the company and put into production. Their approach is to search for balance between generality of approach, and ease (including expense) of implementation into a real product.

The Corporate Advanced Systems Architecture Group has previously developed a fuzzy inference shell, which then was passed on to the Fuzzy Technology Group whose task was to further develop the prototype into a commercial software product.

Knowledge based signal processing

Under this name the Corporate Advanced Systems Architecture Group (hence forth CASA Group) has developed several techniques, commonly referred to as soft filters, for dealing with noise in an image.

Here the term soft refers to the concept of *soft computing*, first suggested by Zadeh, to name a collection of computing approaches including fuzzy logic, neural networks, genetic algorithms, etc. More over, this term may imply a sort of cooperation between two or more of these approaches.

In connection with signal processing, algorithms dealing with real world signal must be adaptive in order to properly manage "scene" characteristics. CASA's position is that knowledge based signal processing is the best approach and soft-computing most promising methodology to realize it.

The following contains a brief overview of the basic ideas and issues considered by CASA Group in connection with fuzzy logic-based signal processing. Knowledge can be used at any stage of the processing - extraction, refinement - as depicted in Figure 10.1.

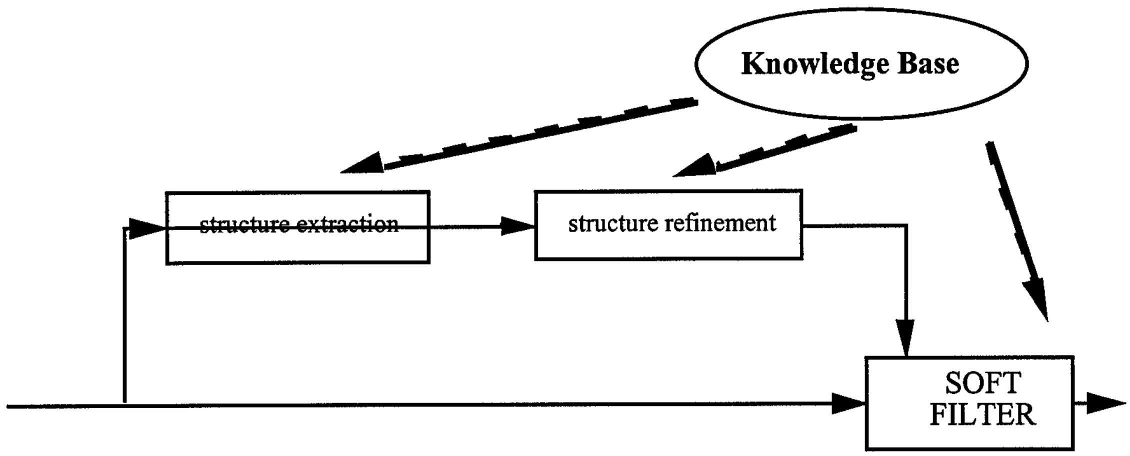

Fig. 10.1 Knowledge can be used at all stages of signal processing to create a soft filter

The concept of improved quality TV (IQTV) has been coined and developed by SGS-Thomson's CASA Group as an intermediate step between the current TV and HDTV. Essentially, the idea behind the IQTV is to achieve high image quality without changing the current transmission standards.

SGS-Thomson has patented "Fuzzy IQTV Processor" as a simple cost-effective add-on component for 16:9 TV chassis. Exploiting the interpolative capabilities of fuzzy reasoning the "Fuzzy IQTV Processor" has the following features:

o drastic reduction of impulsive noise

o adapts automatically local contrast/luminance according to the whole image characteristics

o improves image sharpness and visible details

o allows either standard or progressive or 100HZ image reproduction

The idea behind the approach is illustrated in Figure 10.2

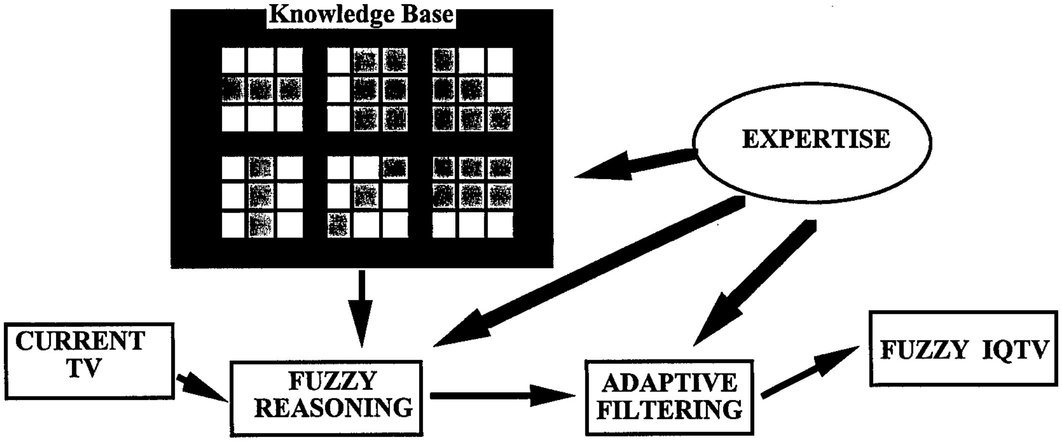

Fig. 10.2 : Using a knowledge base of edge patterns and expertise to obtain adaptive signal filtering

Noise reduction using a fuzzy logic based approach

A knowledge base of typical structures is defined. The knowledge base contains rules for edge detecting. A confidence value for the result, ranging in the interval [0, 1] is associated to each rule. The filtering action is then done according to how edge-like a pixel is, using rules of the form:

IF PIXEL is edge-pixel

THEN **DO NOT Smooth**

ELSE **Smooth**

This approach obtains non-linear and adaptive filters.

Impulsive noise is one the most difficult issues in signal processing. Impulsive noise reduction can be obtained using fuzzy reasoning by applying **fuzzy edge voting** algorithms (Fig. 3).

Starting from edge profiles, the fuzzy edge voters (rule based line operators) are applied in order to detect possible edge structures along a particular direction.

Templates are defined on line operators activation levels, after which line process results are collected in order to detect an edge or noise structure.

As seen in Figure 10.3 fuzzy line processing can be implemented as a parallel or time sharing structure.

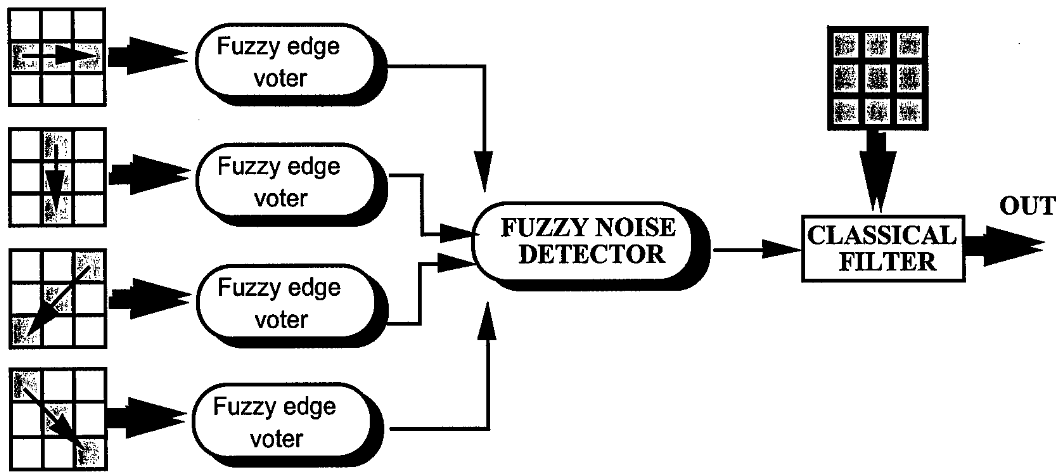

Fig. 10.3: Fuzzy edge detection

Scanning rate up-conversion

The interlaced-scan-related artefacts depend on the video signal bandwidth limitation. They can be overcome by exploiting resolution enhancement techniques. Such techniques are realized by doubling either:

- o the line frequency (interlaced to progressive conversion) or
- o doubling the field frequency (field rate up-conversion) using an interpolation algorithm.

For the latter a rule based system is used to detect both spatial and temporal correlation along particular directions. For each pixel a value K is computed to represent the truth of the sentence "the pixel is moving". Advanced procedures are used to improve motion detection performance; a field memory is used in order to extract motion information.

The procedure is summarized in Figure 10.4:

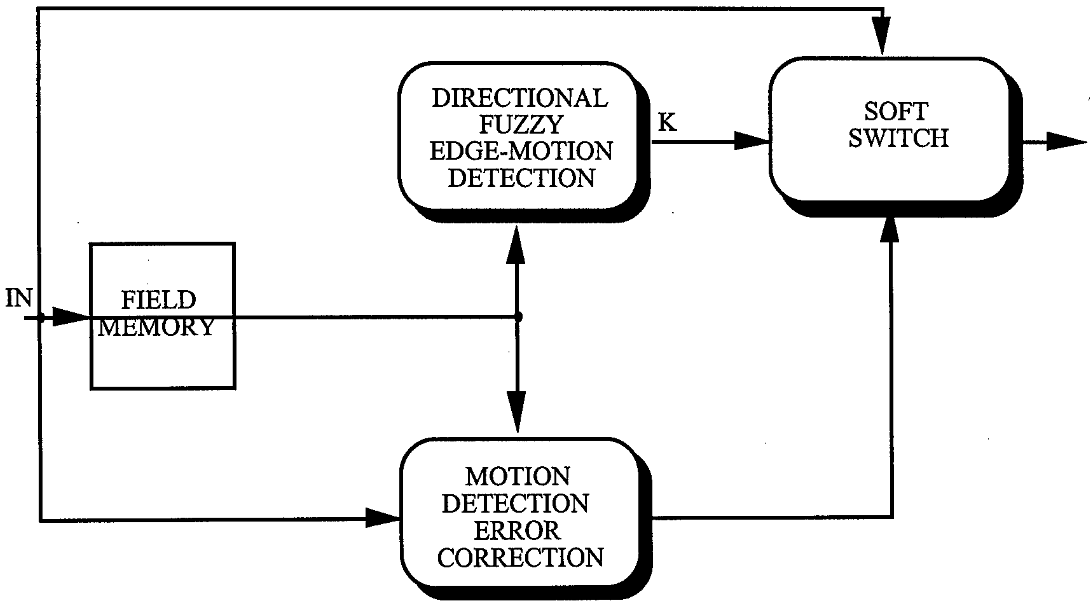

Fig. 4 Implementation of a soft switch

Gaussian Noise reduction: Fuzzy reasoning has been used for this as well according the following steps:

o smoothing on flat areas: low-pass smoothing is performed on a "homogeneous" region using **fuzzy if-then rules.**

o edge preserving smoothing: **fuzzy inference** is performed on a region of the image with significant gray level differences (edges) by:

  o fuzzy template matching: this evaluates the extent to which the region under observation matches with a predefined template

  o fuzzy template smoothing: perform a low-apss smoothing according to the degree of activation of each template.

o fuzzy identification area: fuzzy inference is used to evaluate the extent top which a region can be considered "homogeneous"

o soft switch: this combines the effect of the smoothing actions evaluated earlier on the two different types of area

The Gaussian noise reduction procedure is summarized in Figure 10.5:

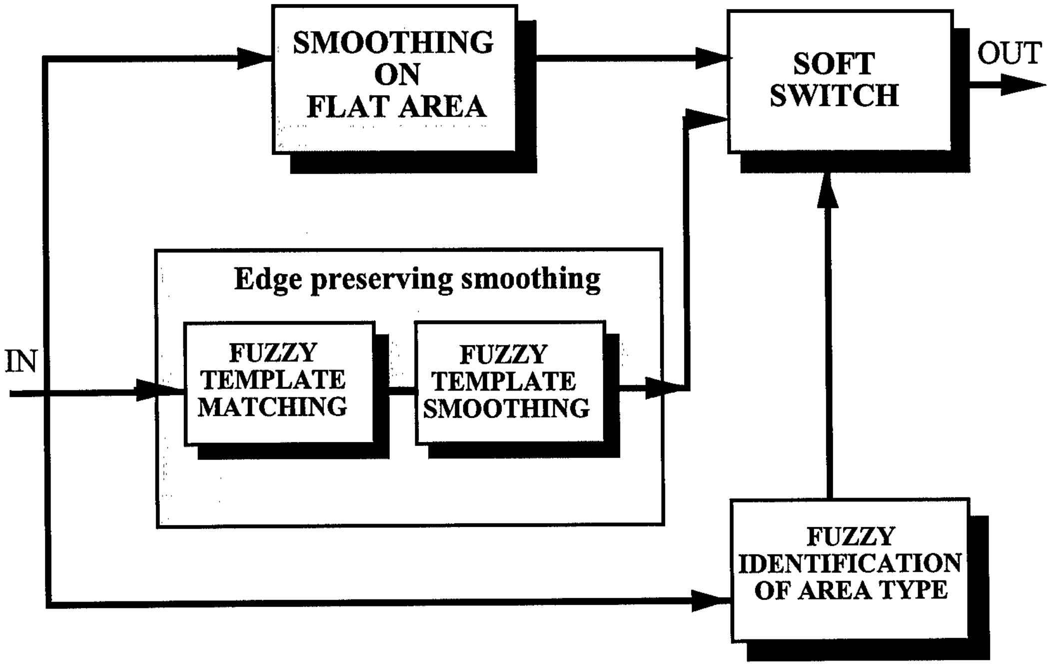

Fig. 10.5: Gaussian noise smoothing by integrating (a) fuzzy smoothing of flat areas and

(b) edge preserving smoothing

The degree to which a region is homogeneous is calculated based on the gray level of a pixel and its neighbors. It determines first of all the size of the filter. The following rule is used for this effect:

IF region is HOMGENEOUS

THEN use a 5×5 filter

ELSE use a 3×3 filter

The integration of the fuzzy flat area smoother (FFAS) and the fuzzy edge preserving smoother(FEPS) is done according to the value of K (which measures the degree of homogeneity) using a linear combination:

$Y_{out} = K\ (FFAS) + (1\text{-}K)(FEPS)$

which implements the rule

IF region is HOMGENEOUS

THEN apply FFAS

ELSE apply FEPS

Dynamic range reduction and contrast enhancement

In this study issues in image enhancement, such as

- o dynamic range rotating
- o cloud cover removal
- o contrast enhancement

are solved by dynamic range reduction and contrast intensification.

In particular, the different dynamic range among natural scenes and recording media reduces details visibility in high and low luminance regions. The fuzzy logic based solution to the dynamic range reduction and contrast enhancement is summarized by Figure 10.6:

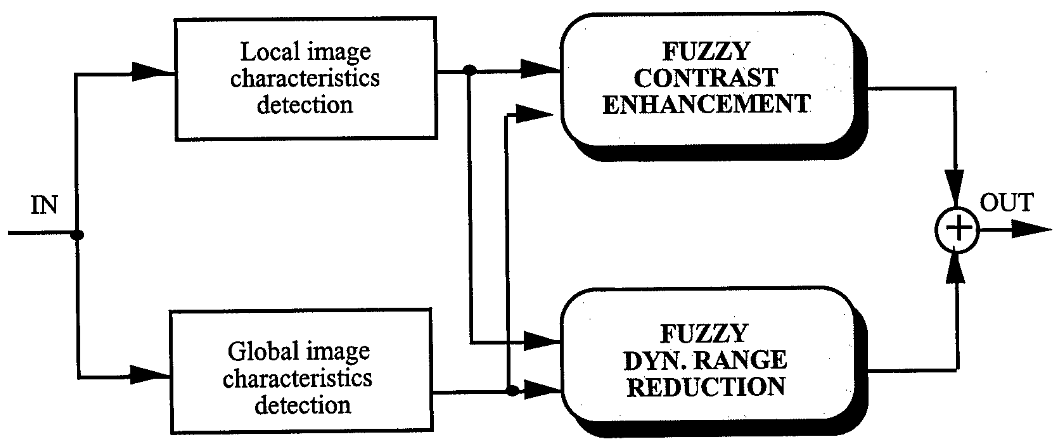

Fig. 10.6: Dynamic range reduction and contrast enhancement

Two fuzzy systems (shaded boxes in Fig. 10.6) are used in order to obtain an adaptive filter. Proper processing curves are automatically determined according to the global and local image characteristics.

Fuzzy Hough Transform (Fig. 10.7)

This classical algorithm for extraction of geometrical features is enhanced by using fuzzy logic in order to

- o embed more robustness to a noisy environment
- o to reduce the computational effort

This is achieved by replacing the usual voting procedure with a fuzzy version implementation of it.

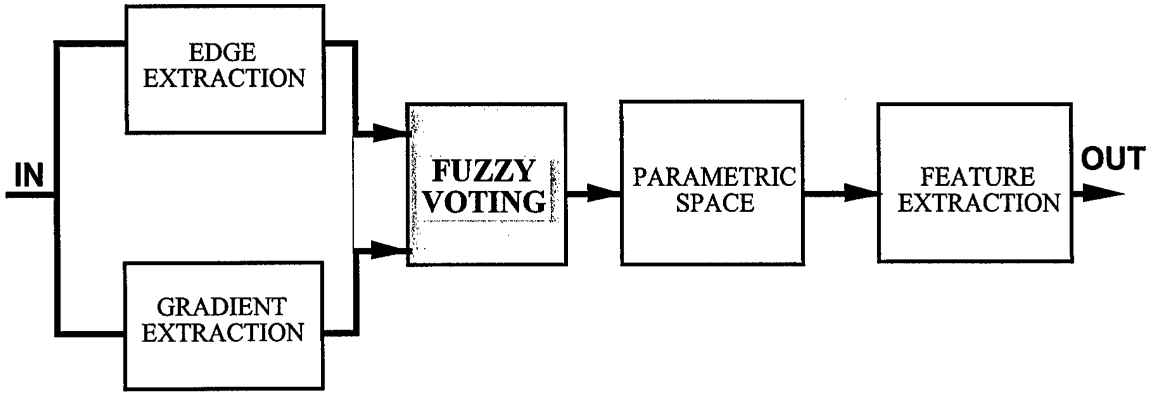

Fig. 10.7: Fuzzy Hough Transform

Conclusion

It quite obvious from listening to the researchers at CASA Group of SGS-Thomson that they have a very good insight into where and how fuzzy logic based methods can help their work. An important aspect of their work (as, for example, in the case of FLS Automation in Denmark) is that they are genuinely concerned with reaching the optimal tradeoff between scientific contribution and salable products (in the case of SGS-Thomson, the new prototypes are submitted to a very drastic censorship process of the marketing department, whose personnel has developed a strong sense of what can be sold and what not). Secondly, and related to the first point is the fact that relatively little of the work done is actually published (FLS Automation has, of course published more, given that it has worked in the area for almost 20 years).

Contact information:

The work reported here was done primarily by Dr. Massimo Mancuso. He and Dr. Poluzzi the head of the CASA Group were the hosts during our visit at SGS-Thomson. They can be contacted at the following address:

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Related bibliography

L. Pennino, M. Mancuso, R. De Luca A Fuzzy Smoother for the Enhancement of Noisy Images, FUZZ-IEEE/IFES'95, Yokohama, March 20-24 1995, Vol. IV, pp. 2025-2032.

11. The Fuzzy Logic Laboratory Linz (FLLL) Austria

General Information

FLLL was founded in November 1991 by Prof. E. Peter Klement of the Mathematics Department of the Johannes Kepler University in Linz. In his mid 40's Professor Klement is one of the pioneers in fuzzy logic research in Austria. His area of research is, however largely theoretical and one is quite surprised to find him in charge of a fuzzy logic laboratory whose activities in applied research have met with a great deal of success and have generated significant prestige and financial gain for this laboratory.

Software park Hegenberg: FLLL is located in the Software park Hagenberg which can be reached after a short car ride from Linz (Fig. 11.1). The whole park has been developed around an old castle and its auxiliary quarters, such as a farm and living quarters of the people working at the castle. Both the castle and the old farmhouse have been renovated according to the current building standards. They offer a very cozy work place, in addition to having found a new life for old/historical buildings. New buildings are being added, mainly offices and student residence halls.

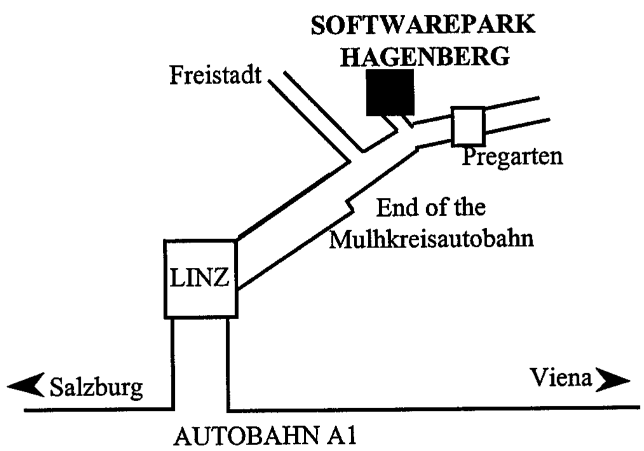

Figure 11.1 Location of FLLL

The Software Park is financed by a group of investors (mainly the RaiffeisenLandesbank) as a private company. It is managed by its initiator The Institute for Research in Symbolic Computation (RISC), and its director Prof. Dr. Bruno Buchberger. Reflecting its special role RISC is located in the old castle, while the other laboratories/companies are located in the adjacent buildings.

The document describing the software park presents it as community of interests (research institutes, companies, training facilities) located under one roof with numerous possibilities for synergy. The common interest is broadly referred to as software, new methods, new tools, new ideas, professional development, application, marketing and training.

Several of the members of the software park are directly related with the Johannes Kepler University in Linz. The last data available (November 1995) show 33 companies/institutes/laboratories as part of the Software Park. Table 11.1 lists these and their corresponding leaders and contact numbers:

Table 11.1 The Software Park at Hegenberg

Name	Description	Contact names	Contact numbers
AMS/STIWA	Software development for CIM, production planning	Dipl.-Ing. Thomas Fuhrer Raphael Sticht	07236/3351 07236/3352
ATI-ART&TECH INSTITUTE	Multimedia (part of the college of art)	Prof. Dr. Herbert Lachmayer	0222/408-48-42 0732/236501-49,50
Becast	software consulting company and produces automatically driven transportation systems (e.g. for production plants). The production of these transportation systems is currently in Germany, the consulting is in the software park.	Mr. Bernhauser	07236 / 3343 - 381
BRUCKNER KONSERVATORIUM	Computers and music	Adelhard Roidinger	07236/3343-670,671
DATA NET	Telecommunication networking	Karl Sengstschmid	07236/3343-470
D2 Consult (previously Mayreder, D2 Consult. it is now a separate company, no longer a daughter of the building company Mayreder)	expertise is in consulting for tunneling building projects	Dr. Schulter	0043/0732 / 33 58 80
ECONIC	software in environmental constructions	Ing. Georg Lehner	07236/3342-900
Eudaptics	software development, especially in process automation and tele-working	Dr. Kranner	0043/7236/33 · 43-388
Evis technologies	software development using genetic algorithms, applications in financial sciences, biochemistry	Mr. Mach	0043 / 7236 / 33 43 -350
FAM ENDFAM	education in tourist industry aspects for women, especially for regional purposes	Mrs. Fuesselberger	0043 / 7236 / 33 43 - 900
FAW	Research institute for applied knowledge engineering	Dipl.-Ing. Christian Gierlinger	07236/3343-761
FHS	Software Engineering (part of the university)	Prof. Dipl.-Ing. Manfred Mauerkirchner	07236/3343-201 0732/673368-14
FLL -Fuzzy Logic Laboratory Linz	**Applied research in fuzzy logic, fuzzy control, industrial applications**	**Univ.-Prof... Dr. Erich P. Klement**	**0732/2468-9151**
GCL- Geomechatronics Linz	software and technologies for tunnel constructions	Univ.-Prof. Dr. Gunter Swoboda	0512/218-4320
GENESIS	Competence center for security, cryptography	Dr. Ingrid Schaumuller	0723/3343-630
GOS-GeoObject Software	Software for geometric problems	Dipl.-Ing. Wilhelm Medetz	07236/3343-56
GODEL-SCHOOL GesmbH	Industrial representative of RISC-Linz	Univ.-Prof. Bruno Buchberger	07236/3231-41
GUP	Research group for graphics and parallel computation (graphics, simulation, parallel processing, super computing)	Univ.-Prof. Dr. Jens Volkert	0732/2468-888

Hirschberg	Technical computations, simulation in kinematics and dynamics, CAE-software for mechanical and automotive engineering, control techniques.	Dr. Wolfgang Hirschberg	07236/3778-40
Isicad - Randtechnologies	software development and education, courses, seminars in CAD and geometric modelers	Mr. Ripota	0043 / 7236/ 66 64
Kaindleinsberger	Tax consultant	Klaus Peter Kaindleinsberger	07236/3343-30
LIZENS	Linz center for Super computing (super computing, high performance computing, networking)	Dr. Friedrich Dirk Valach	0732/2468-432
Mach	Evolutionary programming based on complex machine learning	Ing. Helmut mach	07236/3343-350
Mayreder Consult	Development and consulting for tunnel construction	Dipl.-Ing. Dr. Alfred Schulter Dr. Harald Wagner	0732/6935-249
OEFMS	Austrian Reasearch Institute for Autonomous Intelligent Systems and Microtechnology high-level modelling and simulation of autonomous intelligent systems, modeling and simulation of application processes, tool evaluation and case studies for micro mechanics and new micro technologies	Univ.-Prof. Dr. Franz Pichler	0732/2468-896
Programmierfabirk Hagenberg	Outsourcing software development	Dipl.-Ing. Wilfired Seyruck	07236/3343-252
RISC	Research Institute for Symbolic Computation (computer algebra, multimedia software, neural networks, expert systems, parallel computation, software for technical and industrial applications (CAD/CAM/CIM plant control, simulation)	Univ.-Prof. Bruno Buchberger	07236/3231-41
SAT	Research center for automation techniques	Univ.-Prof. Dr. Peter Kopacek	07236/3343-380
S&A - Systems Techniques & Automation	Research Center for system design and automation, systems engineering, software technology, flexible manufacturing, CASE-environments	Univ.-Prof. Dr. Gerhard Chroust	0732/2468-866
Siemens PSE	Software development group of Siemens, environmental technologies, scientific software, communication technologies, automation, traffic engineering, technological service	Dipl.-Ing. Gerhard Gierlinger	07236/3720-13
SOFT WAREHOUSE Europe	Marketing of computer algebra system Derive, software for mathematics education	Dr. Bernhard Kutzler	07236/3297-81
Source Communication	arts and graphical design	Mr. Hofmueller	0043 / 7236 / 33 43 - 386

UNI Software Plus	Computer mathematics, symbolic computation, software engineering, soft automation, products, projects, training	Dipl.-Ing. Herbert Exner	07236/3338-62
UNSELD + PARTNER	Discrete simulation	Dipl.-Ing. Hans Georg Unseld	07236/3343-270,271
WESELY	designing	Mag. Raimund Wesely	07236/3343-230

In December 1991, FLLL started as a two man operation when Peter Bauer then Klement's student was hired to work in this laboratory. Today, Peter Bauer is the second in command at FLLL, overseeing the daily activity of the laboratory. Prof. Klement divides his time between the university office in Linz and FLLL; in addition to campaigning for his laboratory. The initial funding, of some $30,000 per year, for FLLL and the system science department (Prof. Pichler) came from Siemens. Currently the laboratory has six full time research staff (most working towards their Master Degrees). In my conversation with them I found extremely well articulated young men very much focused on the work they were doing and hence addressing very concrete aspects of it. FLLL is housed in a large room in one of the renovated farm buildings and it is rather modestly equipped (one Silicon Graphics computer, seven PC operating under Linux operating system and two Macintosh power PC's). The support comes from the Austrian government (E. P. Klement's salary), the remaining being self supported from contracts with the industry. Part of the latter are for seminars and workshops on fuzzy logic, its applications and FLLL developed software for experimenting with fuzzy logic (including fuzzy logic control).

A breakthrough for FLLL came in the form of a long-term cooperation contract with Sony for two projects in the field of compact disk production. Sony produces CD's in Austria in Anif (near Salzburg) and Thielgau.

1. Project on picture processing (approximately $200,000 per year): printing labels (picture and text) on CD. Technique is similar to that of Japanese screen printing. Quality control is done by computer (a camera plus Silicon Graphics station). In evaluating the label quality the current evaluation system resulted in a 10% hit rate. However, it was found that 90% of the rejected labels were actually good. The aim of the work at FLLL was to increase the hit rate to 70%.

Since a label is printed in 1.2 seconds, the evaluation process must be done in real time. However, this is difficult with the Silicon graphics which, was needed nevertheless because of the complexity of the signal processing algorithms. In short the set up provided a cumbersome architecture difficult to integrate with user interaction.

First, in order to avoid these problems the first step was to use an analog to digital conversion process. This increased the initial cost of the project by approximately $2,000-$3,000. In this process a picture is transferred in 40 ms.

The basic procedure for evaluation the label is based on comparisons with the master compact disk. This is inspected by three human expert operators, who determine the acceptable disks. Based on this

min/max and tolerance values for the picture quality are determined. The process calls for an aggregation of ranges.

In the old procedure, a newly printed label was evaluated using a pixel by pixel comparison operation. The error was calculated based on the total of pixels out of range.

The new procedure, starts by differentiating between printing areas: background, text, edges. Then the ranges of acceptable errors are adjusted according to the type of printing area considered. This is where fuzzy logic is used. Fuzzy IF-THEN rules are used to determine the type of printing area, and for each printing area to determine the adjustment of range.

The following give some examples of the rules used: After segmentation and edge detection (from which only these deemed visually significant are retained) the following rules are applied to determine the type of printing area:

If the Variance is *small* then the type is *homogenous*

If the Variance is *NOT small* and edge is *big* then type is *edge*

If the Variance is *medium* and Edge is *small* then type is *raster*

If the Variance is *big* and Edge is *small* then type is *Aquarelle*

(here the term *Aquarellel* is used to indicate artifacts - objects in the image).

Mamdani rule of inference *without defuzzification* is used for aggregating results.

Therefore, for a given label region by applying each of the previous rules corresponding values of the degrees to which a rule is satisfied is computed (α_H, α_E, α_R, α_A), which are further normalized (i.e. $\alpha_H+\alpha_E+\alpha_R+\alpha_A=1$). These values are then used to determine the tolerance values ε_H, ε_E, ε_R, ε_A.

Some of the further technical aspects of this work addresses the issues of optimization of segmentation, defining fuzzy sets (work has been done using genetic algorithms), and evaluation of the correctness of fuzzy sets (with respect to the user).

The results obtained at FLLL are now being transferred to the regular production system, and in fact, Sony plans to sell this technology. The performance of the fuzzy logic based approach has been superior to that of the system used by the German company BASLER, which has been "knocked from the first position" it occupied in this particular area.

2. The second Sony project at FLLL (approx. $150,000 per year) is in the production process of a compact disk. More precisely, it addresses the problem of detecting errors when the mold disk is produced. This error appears in the process of transferring, at double speed, the contents of the master

tape, which contains digital noise, on the mold disk. Lost portion of the signal are filled in by a linear interpolation. In general, if the error is known there are already systems for correcting the error. However, the problem is to actually locate the error. Currently, this is done by relying on human sound engineers to locate the error.

Thus, the work at FLLL in this area aims at developing an automatic error location procedure. This is based on a catalog of errors. However, the task is made more difficult by the fact that errors are context dependent, that is, detection of error location may change according to the type of music. Given the context dependency and the fact that a human operator provides to date the best error location procedure, a fuzzy system seems well suited for this problem. At the time of visiting FLLL this project had just started after a two months feasibility study phase. Signal transferred in a buffer is checked for errors (several types of errors have been identified). An additional constraint is that of time - since the transfer is done in double speed the error check must be done in double speed as well. However, since no user interface is needed this can be done using a Silicon Graphics platform quickly and inexpensively.

3. Finally, the third project, supported by the Austrian Science Foundation (ASF) is in the area of fuzzy control. This is carried by Peter Klement, Peter Bauer, but mainly by Brian Moser of the Mathematics Department. It centers on the problem of numerical analysis of the I/O functions induced by fuzzy controllers. In a certain sense these are negative results, discussion the limitations of fuzzy controllers. However, they also address the problem of reducing the rules in a fuzzy system by exploiting redundancies.

At the time of writing this report no literature in English is available on the Sony projects mentioned.

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12. Medical Applications of Fuzzy Logic at the University of Vienna, Austria Department of Medical Computer Science The CADIAG systems

General information

One of the earliest applications of fuzzy logic have been considered at the University of Vienna in the field of expert systems for internal medicine. In a time when elsewhere in the world this topic seems to have fallen out of grace with researchers, the Vienna group, under the leadership of Dr. Peter Adlassnig is strongly continuing on the CADIAG[25] project being now in the course of developing its 4th version.

The CADIAG projects started with a system based on Boolean logic in 1986. In CADIAG-1 relationships between medical entities were represented by first-order predicate calculus formulae; in CADIAG-2 fuzzy sets were used for their representation, and fuzzy logic was used as an inference mechanism. This mechanism was redesigned in CADIAG-3 to include different fuzzy operators and recursive expressions. Finally in CADIAG-4 the research backtracked to CADIAG-2, at the conversion of crisp predicates into fuzzy predicates to consider in this process the dependence between various medical data concerning a patient.

It can be assessed from studying the four versions of CADIAG system that the versions 2 and 4 have presented major contributions.

The underlying clinical issues in the CADIAG system include assisting the differential process of diagnostic:

- by indicating all possible diseases which might be the cause of a patient's pathological finding, with special emphasis on rare diseases;
- by offering further useful examination to confirm or to exclude gained diagnostic hypothesis, or to find stronger support for them; and
- by indicating patients' pathological findings not yet accounted for by expert system's proposed diagnoses.

CADIAG-2 has a knowledge base containing disease profiles and complex rules for 295 diseases, among them 185 rheumatic diseases (69 diseases of the joints, 12 of the spinal cord, 38 of soft tissue and connective tissue system, 45 of the cartilage and bone, 21 regional pain syndrome), and 110 gastro-enterological diseases (35 gall bladder and bile duct diseases, 10 pancreatic diseases, 37 of the colon, 28 diseases of the peritoneum).

[25]CADIAG stands for Computer-Assisted DIAGnosis

Integration of CADIAG-2 into WAMIS[26]

CADIAG-2 is integrated into the medical information system of the Vienna general Hospital. This integration allows the collection of patient's findings for CADIAG-2 via routine medical documentation and laboratory system of WAMIS.

Through a data abstraction and aggregation process patient data is made available to the CADIAG-2 system which tries to infer diagnoses from these abstracted findings. The inference is data-driven.

In addition, patient data can be entered through a man-machine interface which is capable of processing medical terms given in natural language. A word segmentation algorithm allows the use of medical synonyms and abbreviations. In addition it accepts different spellings of a word and takes specific medical suffixes into account.

CADIAG-2 can be used in three modes:

- o screening and monitoring mode: at a very early stage of the diagnostic procedure
- o consultation mode: this is applied after complete data collection
- o textbook mode: when used without connection to the patient data base.

Knowledge representation and inference engine

CADIAG-2 diagnostic process is based on stored disease profiles and rules (usually very complex rules).

The association between findings and disease (antecedents and consequent in rules) is qualified by two quantities:

- o the necessity of occurrence of a certain finding with a disease : this is calculated based on the frequency of occurrence degree;
- o sufficiency to infer disease (strength of confirmation)

The inference process aims at generating one or more differential diagnoses and at the same time at excluding some or all remaining diagnoses. A diagnosis is either established as definitely confirmed (if phatognomonic findings were found in the patient or confirmed rules were triggered by the patient findings); or proposed as a diagnosis hypothesis to be confirmed or excluded after additional examinations are performed.

[26]WAMIS is the German acronym for Wiener Allgemeines Medizinisches Informations-System (Vienna General medical Information System).

Since diseases are viewed in a hierarchical manner, diagnoses at higher level in the disease hierarchy are confirmed as well if sub-diagnoses are confirmed.

Excluded diagnoses are established by either present excluding criteria or absent necessary criteria. Excluding criteria may be single excluding findings, excluding rules or already established diagnoses which exclude others.

When findings and rule criteria defined as necessary for establishing a diagnosis are absent exclude the corresponding diagnosis. Definitely excluded disease categories will cause the exclusion of the entire set of the respective sub-diagnoses.

A special class of diagnoses are **diagnostic contradictions**, which are excluded and confirmed to different degrees at the same time.

These diagnoses are treated separately stating the reason of being established.

Diagnostic hypotheses are generated if a diagnosis is:

- o neither confirmed nor excluded nor contradictory result;
- o the strength of confirmation of at least one present finding, one triggered rule, or one already established sub-diagnosis is equal or higher than a given threshold e ($0<e<1$).

The use of fuzzy sets theory allows for effective modeling of borderline findings by attaching to it a degree of presence of a finding. This degree is combined with its strength of confirmation. If the resulting value exceeds e then the respective disease has to be taken into consideration as a diagnostic hypothesis.

Finally diagnostic hypothesis are ranked according to a score of support, calculated on the basis of:

- o the number of single findings present to a certain degree and having a relationship to the disease under consideration;
- o the degree of presence of these findings;
- o the degree of frequency of occurrence and strength of confirmation between these findings and the respective disease.

Diagnoses which are neither confirmed nor excluded, nor diagnostic hypotheses, nor contradictory results are put into a category denoted by "not generated diagnoses". This allows the physician to obtain a complete survey of all diseases included into CADIAG-2's knowledge base.

Knowledge acquisition is done using two forms which cooperate:

o acquisition of knowledge from medical experts

o emiautomatic acquisition of medical knowledge from a patient database.

Medical experts are very good at providing definition and judgmental knowledge from textbooks and their own experience. However, they are usually less inclined to provide strength and confirmation degrees. For this an automatic procedure is used to calculate these from a database of stored patient records with known diagnoses.

Consistency and completeness of the knowledge base: In CADIAG-1 knowledge consistency and was automatically checked, and inconsistencies corrected. This mechanism can be partially applied to CADIAG-2 as well, due to the homomorphic mapping between the finding-to-disease relationship categories of CADIAG-1 and CADIAG-2.

Clinical test have been performed extensively on CADIAG-2 and reported in the literature. When applied to 544 clinical cases (426 rheumatic cases, 467 pancreatic, 71 gallbladder and bile duct cases) 38 were diagnosed as multiproblem cases. For each of these between 200 and 800 findings were available, which were either present, present to a certain degree, or absent. The large number of findings is the result of complete data collection in the associated medical departments where the tests are being carried out.

Compared with confirmed clinical diagnoses, or if available surgery or anatomic-pathological diagnoses the accuracy was about 92%, where the respective evaluation criterion was whether the gold standard diagnosis was either confirmed or among the first three hypotheses in the ranked list of hypotheses.

The results were best for acute problems where specific investigations such as X-rays provided sufficient medical evidence to confirm or to hypothesize a present disease. Unsatisfactory outcome was obtained in some cases with a history of therapy that had led to improved clinical patterns and closer to normal laboratory results.

In CADIAG-4 the research team went back to the most basic problem of a fuzzy logic based system, that of converting numerical data into symbols (fuzzy sets). Based on the experience with the previous versions it was determined that fuzzy sets for interpretation of a medical datum may require more than the datum itself. Thus, the data-to-symbol conversion was redesigned so at to take into account other information and at the same time allow a straightforward implementaion.

Different methods for doing this were considered as follows:

Fuzzy membership functions with two function parameters:

Fuzzy membership function with two parameters appear frequently in the medical field. For example, the meaning of "*adequate* erythopoietin sysnthesis" depends on the "hematocrit level" (Figure 12..1).

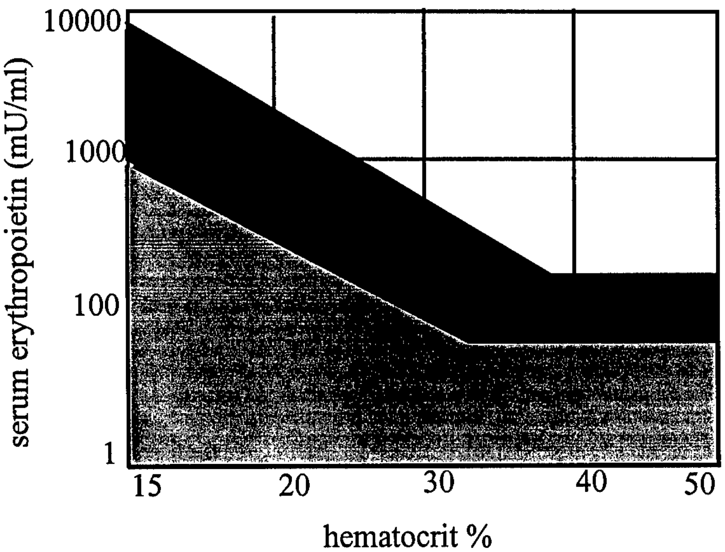

Fig. 12..1 Range of adequate erythropoietin synthesis as a function of hematocrit during pregnacy.

The definition of such membership functions is reduced to a procedure in which the membership function is determined for one parameter, for fixed discrete values of the second parameter. For other values of the second parameter a linear interpolation procedure is used to obtain the corresponding membership function describing the second parameter. Fig. 12..2 illustrates the result of this procedure for the example considered here.

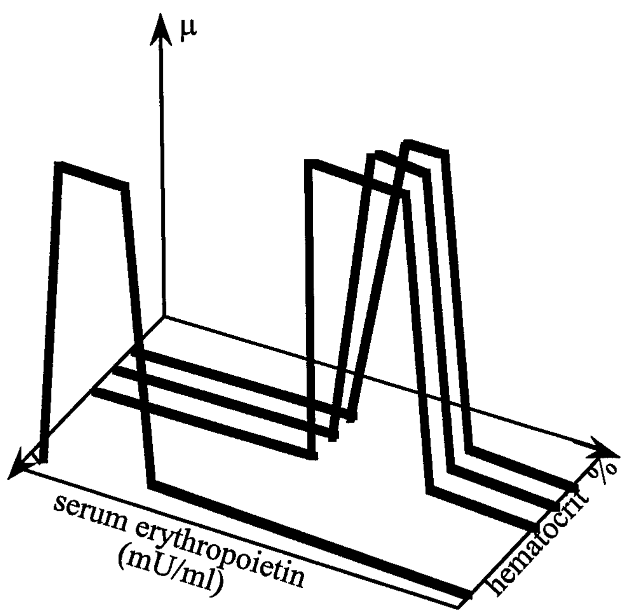

Figure 12..2: Two dimensional fuzzy sets defined by fuzzy membership functions with two parameters.

Fuzzy membership functions representing fuzzy trends

A similar situation arises in the case when the medical datum is to tracked over a period of time. Temporal changes are very relevant to clinical interpretation. Fuzzy trends are a special case of the membership functions with two parameters. The length of the temporal interval establishes a time window for the observed parameter. The trend can be both estimated and assessed retrospectively. The

fuzzy trend indicates in effect two phenomena: the trend in the range of values for the variable of interest, and the trend in the membership function values. Four types of trends are recognized in CADIAG-4:

- o constant trends
- o rising trends
- o falling trends
- o oscillating trends

Context-specific fuzzy sets

The need for context-specific definitions of fuzzy sets has been long recognized by the fuzzy logic community. In passing it should be also mentioned that context-dependency (lack of) is not an issue specific to fuzzy sets. Indeed, suppose that meanings of concepts such as *tall* were defined using frequency distributions, it is clear that dependency is (or is missing) according to how data is collected.

Contexts themselves can be defined as fuzzy sets, from medical data by a data-to-symbol conversion procedure. A particular patient can be assigned a degree to which it belongs to knowln contexts. The final interpretation pf the corresponding findings are then within the context with highest degree of membership.

Implementation of data-to-symbol conversion

During the knowledge acquisition process one or more fuzzy sets must be defined for the interpretation of a medical datum. The number of fuzzy sets increases due to the following reasons:

- o the origin of a parameter is defined by different procedure. Thus, for each procedure fuzzy sets must be established.
- o different authors can define user-specific fuzzy sets
- o for different context context-specific fuzzy sets may be defined.

Given a medical datum one must take into account all the fuzzy sets aplicable to its interpreation. To this end CADIAG-4 such fuzzy sets are combined into Qualified Fuzzy Sets Collections(QFSC).

The inference process in CADIAG-4 is designed such that the symbols generated in one cycle of of inference can be used as new fuzzy contexts for the next cycle. This ensures a continuous update of the interpretation of the medical data concerning a patient (Figure 12..3).

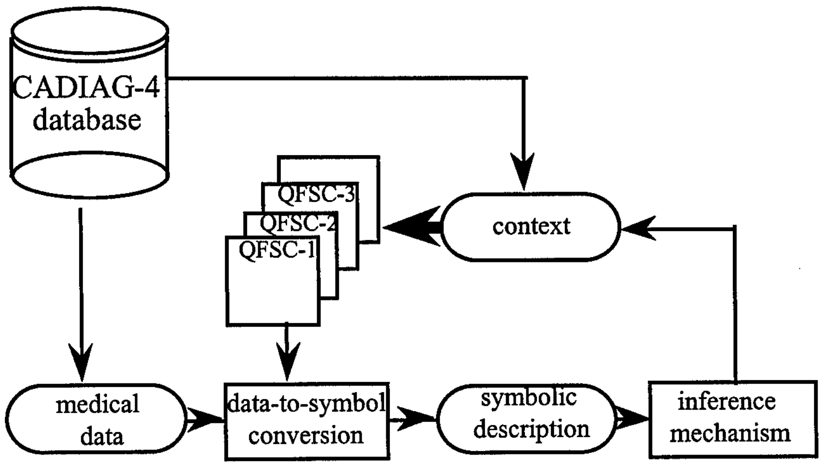

Fig. 12..3 Recursive interpretation of medical data and computation of QFSCs.

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13. Fuzzy systems technologies at Siemens R&D

General Information

Siemens is one of the largest company worldwide on electrical and electronic industry. With manufacturing and sales in 123 countries: therefore more than 50% of Siemens' business comes from outside Germany. Thirteen groups and several special divisions covering the areas of industrial automation, power generation, semiconductors, public and private communication networks, automotive and transportation systems, audio and video systems.

Strong research and development program lead to the current situation in which more than 50% of the production is in electronic products and systems. Siemens' research budget of DM 7.0 billion per year is one of the largest in Europe.

Siemens' Fuzzy Research Group comprises approximately 12 permanent people; in addition, it has an average of 6-7 PhD- and MSc-students, and a visiting researchers (e.g. Professor Dimiter Driankov of Linkoping, Sweden visits every year during the summer for 4 months). The group grew out of a task force which was created in January 1991 with three people and grew quickly to even a larger size than the current group. In the most recent times, the group seems to experience some difficulties, as Siemens has shifted from a company supported research to contract supported research, that is, even fundamental research groups are strongly encouraged to seek outside research support, through cooperation with other companies. The Task Force Fuzzy is located within the R&D Center. Its mission is to coordinate and support fuzzy activities within the Siemens group. Rationale for creating this task force include:

- superior performance at low cost of development and implementation: both these aspects of fuzzy control have become evident from the wide range of fuzzy control applications realized in Japan. (It appears that Siemens saw the Japanese experience as a possible a threat, and one of the missions of the Fuzzy task was that of bringing Siemens, as soon as possible to the state of the art in fuzzy technology).

- for ill-structured problems (linearity and time invariance cannot be guaranteed, significant transport lags, random disturbances) the fuzzy control approach appears to be useful for identification and control

With respect to research Siemens adopts the view that only application-driven, experimental research "can be sufficiently focused and guided in the right direction to make good progress".

The difficulties in applying the existing theory (of fuzzy control) to practical applications include the following:

- lack of a good and systematic technology which should address the following issues:

- o what are the proper design choices for a given problem
- o robustness
- o stability

o documentation of applications: successful and unsuccessful

There should be no expectation of a universal approach which can be of any practical use; such an approach does not exist even for the conventional control engineering either.

Projects in fuzzy control at Siemens

o automobile technology:

o fuzzy automatic transmission system

o fuzzy idle speed control.

o traffic technology:

o fuzzy anti slip control for trains

o fuzzy parking place forecasting system

o fuzzy traffic light control

o fuzzy speed control in highways

o domestic appliances:

o washing machine

o vacuum cleaner

o Industrial applications

o chemical applications: paper processing system (implemented in a paper processing plant in Portugal).

o power stations: H2-leakage diagnosis system

MOST PROJECTS AT SIEMENS ARE EXTREMELY CONFIDENTIAL.

Difficulties associated to the current fuzzy technology include:

o lack of expertise among control engineers in the field of fuzzy control

o lack of instructional material (while there are a rather large number of texts on various aspects of fuzzy logic related issues there are hardly any good textbooks).

o there is no systematic knowledge of the correspondence between problem types and specific approaches.

o there is no general design methodology. Siemens is addressing these difficulties internally; it has developed courses (Helendoorn has written a book on fuzzy control) which have been taught internally; the last two points are ongoing subjects of study at Siemens. Thus, it is expected that by its work on fuzzy technology, addressing the four points above Siemens will impact beyond the company specific goals of becoming competitive in this domain; in fact it will contribute to the general advancement of fuzzy technology.

The Fuzzy Task Force has also been assigned the project of developing software tools to support the implementation of fuzzy controllers. Thus, in collaboration with Togai Infralogic Siemens has developed SieFuzzy, a new version of TIL-Shell.

Characteristics of SieFuzzy

o SieFuzzy is a software development tool for:

designing fuzzy logic systems

testing the systems developed through simulations

on-line testing (compiled code)

compiling the resulting system into any variant of C-code.

o SieFuzzy comes with editors for each part of the fuzzy system:

membership function editor

rule matrix and rule table editor

o The description of a fuzzy system is represented in the Fuzzy programming Language (FPL^{TM}). Changes made with one of the editors are updated automatically in the FPL descriptions of the system.

o Testing and tuning facilities:

static testing: specific values for the system inputs are entered and the output values are observed or plotted in a 3-dimensional representation of the relationship between inputs and one output of the system.

A cursor can be moved along the control surface; the rules and membership functions responsible for that area of the surface are identified.

dynamic testing: the system can be tested as it runs with a simulation of the final application and the behavior of each rule can be observed, the corresponding membership function and rule interactions.

Advanced features of SieFuzzy include:

DDE support: Dynamic Data Exchange under MS-Windows. With this SieFuzzy can be linked as either a client or a server to other applications which support DDE (MATHLAB, SIMULINK); it can also be liked to another instance of SieFuzzy.

user-defined extensions of the FPL: these are used to for defining fuzzy operators, objects and inference/defuzzification methods.

user-defined utilities: these are used for calling other applications from a user-defined SieFuzzy menu command.

Other data about SieFuzzy:

Developed jointly with Togai InfraLogic, Inc, and Siemens AG. "TilShell 3.0 Professional Edition" is the Togai InfraLogic Inc. proprietary name for SieFuzzy 1.0.

SieFuzzy is a Microsoft Windows 3.1 program requiring an IBM compatible PC with at least a 386 processor and 4MB RAM recommended.

The following examples are representative of Siemens' work in the area of implementing fuzzy systems. Fuzzy control, fuzzy diagnostic systems and fuzzy classification systems are differentiated according to the role a human operator plays during the functioning of such a system (Table 13.1):

Table13.1: Types of fuzzy systems developed at Siemens

type of system	operator role	implemented example
fuzzy control	no operator (closed loop)	vacuum cleaner: sensors sense the amount of dust and type of carpet to adjust suction power)
fuzzy classification	no loop/no operator although the operator can intervene	fuzzy washing machine: the type and amount of laundry are used to set the parameters of the wash (cycle); fuzzy automatic transmission system: sensors available in the car (e.g. from the AB system, power steering, motor control) are used to determine the state of the car (loaded, uphill)

fuzzy diagnostic system	operators play an explicit role: provide additional input upon explicit request from the system; similar to a fuzzy expert system (rule base system in which antecedent and consequent of rules contain fuzzy predicates).	H2-leak diagnosis system

The following describes specific application for each type of system shown in Table 13.1.

In connection with the fuzzy control work Siemens has addressed several theoretical issues, as follows:

sliding mode fuzzy control (SMC): it was observed that the performance and the robustness of the fuzzy controllers for non-linear 2nd order systems are due to the fact that the systems are driven in a sliding mode in which the controlled system is invariant to parameters fluctuations and disturbances (robustness). This makes possible the analogy of a fuzzy controller to a sliding mode controller which has an additional boundary layer. In turn this can guide the selection of parameters and the principle can be extended to higher order systems.

tuning of scaling factors: Scaling refers to the mapping of input values into values in a universe of discourse on which the membership functions associated to the manipulated variables of the controllers are defined. In the case of stationary system the optimal scaling parameters correspond to the strongest statistical dependency between input and output. Correlation and the coefficient of correlation are used to assess statistical dependence, and it is shown that optimal scaling is characterized by the values of the correlation coefficient of the scaled input to the controller and the defuzzified normalized output. The scaling also depends on the input properties, on the shape and position of the membership functions used and the dynamics of the system.

fuzzy inputs (stability): one of the most common applications of fuzzy controllers assume crisp input values. However, in a more realistic situation the input cannot be guaranteed to be crisp. In fact, a fuzzy input will be arrived at in several ways: (i) present the input simply as a fuzzy set, (ii) consider the noise in input, more precisely its distribution interpreted as a possibility distribution. The differences between the crisp and fuzzy inputs are due to the complexity of the transfer function of the fuzzy controller. This transfer function depends very strongly on the width of the support of the fuzzy set used as input.

integration of linear and fuzzy control : fuzzy controllers are suitable for nonlinear control problems. Linear controllers which work better near the set point of a nonlinear process. For this reason a hybrid approach, according to which linear controllers are integrated in a fuzzy controller is expected to take advantage of the best features of each type of controller. Siemens has developed a method whereby for a

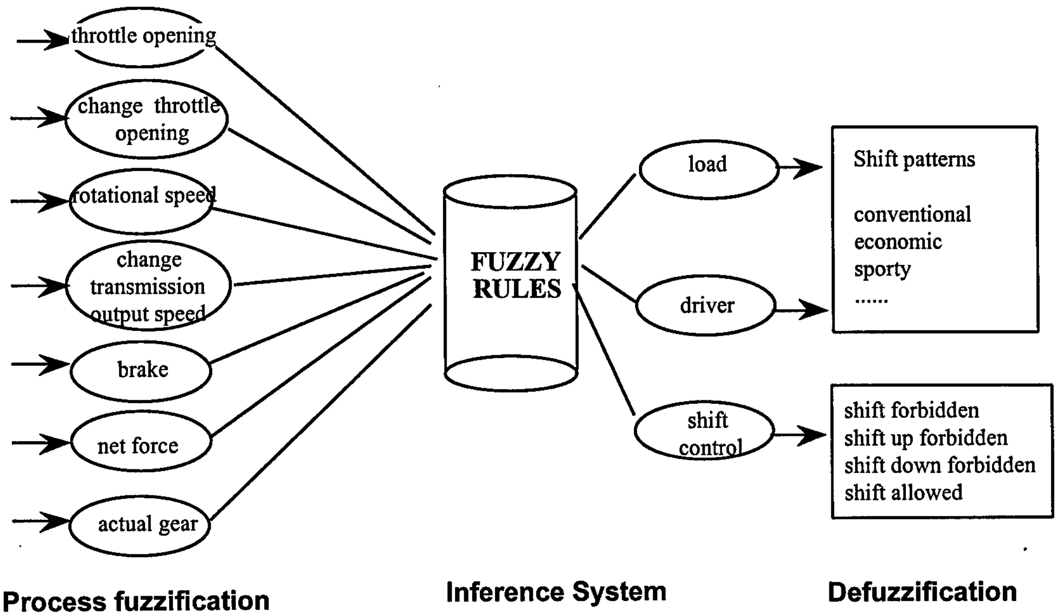
given linear controller (its coefficients) and a hyper cube within the input space of the controller, an equivalent fuzzy controllers is obtained (when the input is within the hyper cube). That is, the membership functions of the input/output variables, as well as the rules relating these variables are obtained.

(Fuzzy) classification systems

Fuzzy classification was adopted in two types of projects: automatic transmission control and automatic washing machine. In each of these based on the input to the system a commitment to particular values of the output takes place.

The application of fuzzy logic to automotive problems goes back to the early 80's with the speed control developed at Kyushu Institute of technology. Since then it remained a very hot application field, now not only in Japan but also in Western Europe and USA. Unfortunately, most of the projects going on n this area are usually confidential. This means that we are able to document quite exactly the results but not the current research.

The idea behind the automatic transmission control is to be able to take into account not only the speed but also other factors, such as the environment, the type of driver, etc. Current shift maps (sporty, defensive, winter) cannot be used to optimally adapt the transmission gear ratio to all possible driving conditions. Modern cars can detect more of the environment conditions if they are equipped wt additional sensors. This in turn increases the price of the car. In the fuzzy ECU (Electronic Control Unit) developed by Siemens only the sensors normally available in the vehicllewere used.The vehicle can be operated in two ways: (i) changing the throttle opening, annd (ii) activatng the brakes. The fuzzy EECU receives seven input signals. It generates three output signals: onefor driver cassification, one for load detection and fnaly one indicting whether a shift is alolowed or not. The driver and and the output signals are used to select the a situation dependent shift.



The relative change in the input signals - such as the change in the throttle opening and the change of the transmission output speed or vehicle acceleration.

Three output quantities are calculated by the controller: type of load, type of driver, shift control. Classificatiion is used for the first two. There are three classes for load: mountain, plain, valey. The rules for mapping input signals into these classes are derived from the net force, more precisely from the quantity DF a measurment of the load including climbing and air resitance (DF is obtained from a refernce force and the kknown parts of the driving resitances). Examples of rules for detecting inclinations incude:

IF DF is POSITIVE THEN LOAD is MOUNTAIN If (DF is POSITIVE) and (BRAKE is NOT PRESSED) THEN LOAD is MOUNTAIN

Load is also indicated by the driver's behavior - and heuristics capturing this :

IF (throttle opening is *very* BIG) and (rotational speed is NOT *very* BIG) and (the change in the rotationall speed is NOT POSITIVE) THEN LOAD is MOUNTAIN

Driver classification: defensive, medium, sporty.

The classification depends on the change of rotational speed and the moving average of the absolute changes in the thorttle opening:

IF (moving average of the absolute changes in the thorttle opening) is HIGH and (the change in the rotational speed) is HIGH THEN driver type is SPORTY

In connection with the shift system security must be taken into account. hence, in addition to classification, a priority of rules must be established to resolve connflicting rules (shift_allowed, shift_forbidden). For safety in this case shift_forbidden should be the final decision.

To implement a priority system, two different mechanisms have been considered:

- membership functions area-based: priority is a function of this area; therefore, under a center of gravity defuzzification method, rules whose output correcponds to large areas of the membership functions have higher priority.

- special purpose defuzzification method: a similar effect to that of the above mechanism is obtained by implementing a modified center of gravity method, in which the center of gravity is affected by al the weighted areas correspondig to a particular linuistic output. Thus, this mechanism allows to factor in the number of rules supporting a conclusion.

The rules for the shift signal are as follows:

IF Gear is GEAR1 THEN Shift sgnal is SHIFT_DOWN_FORBIDDEN

IF Gear is GEAR2 THEN(Shift signal is SHIFT_UP_FORBIDDEN)

A common problem in the automatic transmission vehicles is their behavior when traveling down hill: usually there engine braking (on which manual shift vehicles rely in this mode) does not act as desired in addition to the normal brake. To add this behavior the follwoing rule, which is meant to assure that the gear position is as small as possible:

IF (DF is NEGATIVE) and (brake is PRESSED) THEN (shift signal is SHIFT_UP_FORBIDDEN)

The approach outlined above can be extended to include further aspects concerning the driver, car, environment. For example, in the same manner the driver's driving intention and expectation from the automatic transmission can be coded; the state of the car: load and age of engine; environment information: state of the road (wet), type of road (with many curves).

Siemens fuzzy washing machine: Siemens fuzzy washing machine Siwamat Plus 3773 was introdced in 1993. At that time already a number of similar products have been introduced in Japan. However, Siemens makes a very good job in explaining exactly what the problem is and why fuzzy logic is approapriate for its treatment.

More precisely, the problems in washing machines are vibrations produced during the spining process. In principle these problems can be correctd by making the machines very heavy (e.g. by putting a concrete block in the machine). However, this increases the cost of shipment of the machine and therefore ultimately the cost of the machine itself. Another aspect is that the size of chips in a washing machine has to be as small as possible. This limits the kind of processes that can be programmed in the machine (Siemens' washing machine has an 8 bit ST6 microcontroller with only 64 byte memory).

Fuzzy classification is used in the washng machine to determine the type of spining needed. The classification stems from the interaction between the drive and the movement of the laundry inside the machine.

The difference between the crisp and fuzzy solutions is illustrated by the following examples:

In a crsip approach the control of the spinning is done by considering cases associated to three intervals of the Drpm range:

If (Drpm < 35) then the spin speed is high

else

If (Drpm <108) then the spin speed is low else abort and start again.

The fuzzy rules take into account not only Drpm but also the load in the machine:

IF (Drpm is SMALL) THEN spin speed is *very* HIGH

IF (Drpm is MEDIUM) and (load is NOT MEDIUM) THEN (spin speed is HIGH)

IF (Drpm is MEEDIUM) and (load s MEDIUM) THEN (sin speed is HIGH)

IF (Drpm is BIG) and (load s NOT MEDIUM) THEN (spin speed is LOW)

IF (Drpm is BIG) and (load s MEDIUM) THEN abort and try again

Fuzzy Diagnostic system

As mentioned previously in this section the distinction between (fuzzy) diagnostic systems and expert systems from classification systems lies nt eh roe of the human user/operator. In addition to being able to intervene in the system by suppling more information or refining the information already in the system, the user has also to be given the opportunity to interaogate the syetm aout its workings, thus expnantion faciities in terms easily understood by the system are needed.

Fuzzy logic based diagnostoc systems are especially useful in the case of diagnostic problems for which a mathematical model does not exist (such as large plants or complex processes).

The advantage of fuzzy logic is lies in different drections:: (i) expert knowledge about the problem can be easily coded into fuzzy rules, (ii) avoidance of incmplete and/or inconsistent knowledge bases (iii) suvtantial smaller knowledge bases increasing readability of the system.

The diagnostoc system for H_2-lekage developed by Siemens is typical of the problems n which fuzzy logic is the abvious tool.

This system is about detecting eakage in high performance generators cooled using water and hydrogen.

Uncontrolled hydrogen losses must be kept to a minimum, under 12m3/day.

However, hyderogen losses are difficult to measure - evidence of such losses comes from their effects (or symtoms): pressure changes and hydrogen make-up. Things are more complicated by the fact that these symptms are associated to other causes as well. Finally there are nomathematical models for the process of hydrogen comsumption.

To evaluate the hydrogen compsumption a hydrogen sealing mdule perfoms the following tasks:

monitoring and anlisys of gas cnsumption

early leak detection

early leak localization

Fifty diagnostoc variables (primary and gradients) are monitored and depending of the represenation method and logic used rules can be very complex. An example of possible rules is

IF (H2 consumption is HIGH) and (apparent power is LOW) and (the hot gas temperature is LOW or FALLING) and (H2 pressure in the generator frame is NOT LOW or FALLING)

THEN the increased H2 consumtion can be attributted to a DECREASE in Temperature

The fuzzy ogc based system converts expert knowledg of this process into fuzzy rules, in which memberip functions can be easiy edited (using the TIL Shell) in to a form easily used by computers.

Moreover, specific rule chanining operators, which can capture an expert's understanding of the problem can also be specified.

Development and testing has been done on a PC in the framework of TILShell; the complete knowledge base ported on a workstation has 51 input variables, ten state variables, 42 output vaiables and 13 rule bases (with a total of 109 rules).

An average of five to ten sensor data values are used to evaluate the conditions of rules. Evaluation of an inout data record requires less than 0.2 seconds on a 880386, 33 MHz floatng point coprocessor, which is a very short time especially considering that in each cycle all rules must be evaluated.

An interestng contribution of this work, besides the obvious one of the whole system actually owrking, is the extension of the regular fuzzy logic operators with two types of implication operators, called weakening and intensifying. Briefly these consists of the following:

Considering two facts a and b and let c=Intensify(a, b). Then c>a (in terms of trth value). Intesify wrks as follows: if b holds and a>0 then a is enhanced by b; if however a>0 but b=0 then a does not change; finally if a=0, b>0 will not change a. This can be summarized in the following truth table:

b \ a	0	>0
0	0	a
>0	0	>a

An example of an intensifying operator is I(a, b) = min(1, a+kab) where k>0 is constant controlling the intensification.

In an analogous way, the weakning operator is defined by the following truth table:

b \ a	0	>0
0	0	a
>0	0	<a

An example of the weakening operator is W(a,b)=max(0, a-kab).

A list of possible diagnostics is maintained as the result, each with a degree of fullfillment. Unlike contro systems where the reult, a control action must be a crisp value (obtained by defuzzification) the result here requires no defuzzification.

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Related bibliography

H. Hellendoorn and R. Palm, Fuzzy Systems Technology at Siemens R & D. Fuzzy Sets and Systems 63 (1994) 245-269

14. GMD - The German National Center For Computer Science System Design Technology Institute (SET) - Innovative Application Design (EIA)

Well known in Germany and abroad GMD is at the center of the research in information technology - both from hardware as well as software point of view.

Here some the work using fuzzy logic done within the Innovative Application Design group located at Sank Augustin near Bonn is presented.

This work includes two projects:

- o a fuzzy logic controlled autonomous vehicle (MORIA)
- o fuzzy rule based approach to on-line handwriting recognition

MORIA - the fuzzy logic controlled autonomous vehicle

MORIA's objective was to develop a collision free autonomous vehicle for indoor environment. The approach uses a reactive goal-oriented navigation system based on fuzzy set theory. Through this approach environmental uncertainty (rather than exact geometric models) can be dealt with. Two components cooperate for controlling the vehicle:

- o the planner which specifies the global driving directions such as **turn left at the next junction"**
- o the navigator which explores the local environment and selects the appropriate path

Unlike conventional systems the navigator reacts quickly to changes in the environment: upon meeting an unexpected obstacle in its path the vehicle reacts very quickly and tries to avoid. If the obstacle is a human, who at the same time tries to avoid the vehicle by blocking the vehicle's newly selected path the vehicle will again change its path, and so on, this shift continuing until the human gives up in trying to block the vehicle (this resembles very much to the real life situation involving two persons).

MORIA's properties

- o fuzzy logic makes possible to deal with inaccurate information (noisy environment, changes in the environment)
- o path description can be done in a very human friendly manner using linguistic descriptions
- o real-time reaction is achieved by implementing the collision avoidance strategy at the navigation level

Implementation

- o ultrasonic sensors are used to collect environment information,
- o fuzzy strategies are implemented both for the planner and navigator,

- o sensor information is converted into linguistic values "near", "far away", "junction detected at left", which is used by the navigator for control,
- o linguistic information is given to the planner to build a topological map of the operating environment The use of linguistic structures reduces the need for the need for memory space,
- o real time response,
- o low cost hardware implementation,
- o simulation tools developed emphasize the inter-changeability between simulation models and reality.

The project was one of the winners of the fuzzy robot competition held in conjunction with the conference FUZZ-IEEE/IFES'95 in Yokohama, Japan, March 1995.

Handwriting recognition

This work is done in conjunction with the UNIPEN competition for handwriting recognition methods.

The system developed, fuzzy on-line handwriting recognition system (FOHRES), relies on developing and optimizing character recognition fuzzy rules (Figure 14.1).

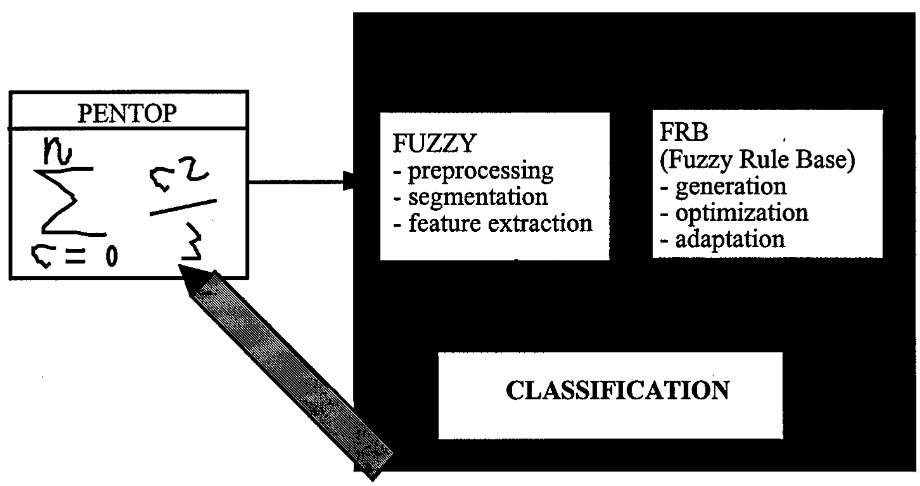

Figure 14.1 Outline of FOHRES

The vagueness of handwritten characters is estimated in three processing stages:

- o preprocessing: ow level noise such as pentop errors are eliminated

- o feature extraction: fuzzy features such as *vertical left line, thin wide symbol, D-like, D-like curves*, are used here

- o rule generation classification: genetic algorithms are used to optimize fuzzy linguistic rules to form a knowledge base of fuzzy classification rules. Rules are initialized using statistical information and optimized using the genetic algorithms.

Experimental results

Initial tests on the handwritten data acquired from five different users were performed. with the rules obtained from statistical information a 72.5% symbol recognition accuracy was obtained. After rule optimization all but one symbol was correctly recognized.

The final rules achieved 97.25% recognition over the training date, and 90.4% for test data of handwriting of other five users.

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Related bibliography

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15. EUFIT, ELITE, ERUDIT

EUFIT (The European Conference for Fuzzy and Intelligent Technologies) series of annual conferences have started in 1993. The man behind these conferences, as well as behind much of the fuzzy logic related work in Germany is Hans-Jurgen Zimmermann, Professor at the Aachen Institute of Technology. With almost 40,000 students and six colleges the Aachen Institute of Technology, mostly known by its acronym in German, RWTH, is the largest institute of its kind in Europe. Zimmermann has created a number of companies catering to different needs regarding information technology in industry. Most known are INFORM and MIT which produce software (expert systems shell like), or offers various maintenance services. He has also funded ELITE, the European Laboratory for Intelligent Technologies, which according to him "..has as the main goal to advance and facilitate the European cooperation in the area of Intelligent Techniques". In fact, Zimmermann runs all his activities from and through ELITE.

While fuzzy logic based research forms the core of the presentations at the EUFIT conferences, a strong interdisciplinary aspect is encouraged. In this respect the EUFIT conferences have proved to be an excellent opportunity for people in various "walks of intelligent systems" to meet and exchange ideas. Typically the topics covered by the presentations made at EUFIT cover, Mathematics (including logic, and methods for uncertainty management), Computer Science, Physics, various engineering fields (Control Engineering being strongly represented), Psychology, Decision Theory, Operations Research, Artificial Intelligence.

Table 15.1 details the participation at the EUFIT in 1994 and 1995. Figure 15.1 shows the participation according to the geographical regions and countries. Table 15.2 contains statistics about papers submitted at the conference, while Table 15.3 shows

Table 15.1: Participation at EUFIT conferences in 1994 and 1995

Category	**EUFIT'94**	**EUFIT'95**
University	292	**303**
Industry	146	**178**
students	60	**63**
other	48	**68**
TOTAL	546	612

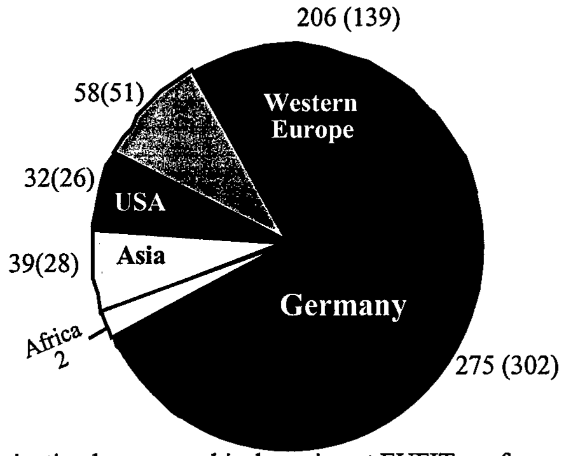

Figure 15.1 Participation by geographical reagion at EUFIT conferences in 1994, 1995.

Table 15.2: Presentations at EUFIT conferences in 1994 and 1995

	EUFIT'94	EUFIT'95
Participants	546	**612**
papers submitted	386	**426**
papers accepted	356	**302**
semi-plenary talks	5	**7**
oral presentations	276	**212**
poster presentations	80	**90**
exhibitors	20	**20**
	Germany: 18; Netherlands: 1; USA: 1	

EUFIT'96

The Fourth European Congress on Intelligent techniques and Soft Computing, organized by ELITE Foundation of Aachen, Germany, will be held Aachen (Aix-la-Chapelle), during September 2-5 1996. The announcement for the conference stated that "..it aims to bring together scientists and practitioners from academic, governmental and industrial institutions to discuss new developments and results in the field of intelligent technologies". The following tracks/topics will be represented at the conference:

o Basics of Fuzzy Sets Theory and Uncertainty Management

o Neural Networks - basics and Applications

o Genetic Algorithms and Evolutionary Computing

o Fuzzy Sets in Artificial Intelligence

o Neural-Fuzzy Systems and learning

o Fuzzy Control- Methodology and Applications

o Decision Support Systems

o Data Analysis and Signal Processing

o Pattern Recognition and Image Processing

o Applications in process Industry and Production Planning

o Medicine and Biomedical Applications

o Financial Engineering and Forecasting

o Software, Hardware, and Standards

o Panel Discussion on Intelligent Applications in Industry

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ERUDIT - European Network of Excellence in "Uncertainty Techniques development for Use in Information Technology" started by the European Commission (DG III Industry - ESPRIT Programme) at the beginning of 1995, has the goal to put European industry at the leading edge of international competitiveness in information technology.

ERUDIT has been currently set up for a period of three years 1995-1997. It is hoped that it will grow and it will extend beyond this initial term.

The 'active nodes' of the network consist primarily of departments in European universities, industrial and trade companies, as well as public institutions, scientific and practitioners in applied research institutions.

In addition to these active nodes, ERUDIT makes possible a looser connection with interested parties which are not based in Europe. These form non-active nodes, in the sense that while they will have access to information about ERUDIT related activities, research, and projects, they will not participate in matters of policy about these.

The active nodes of ERUDIT are organized in various committees (to be detailed below).

The ERUDIT Service Center located within ELITE coordinates activities of the network and provides nodes with the following:

o set-up of the World Wide Web server,

o preparation and dissemination of reports, including those on ERUDIT meetings

o information on existing applications and products and on future events,

o reports about nodes or other institutions and their activities,

o product description and their use,

o provide a corpus of typical problems,

Tables 15.4 and 15.5 show the geographic distribution of the active ERUDIT nodes and the individual active nodes of ERUDIT with the corresponding contact information, at the end of 1995.

Table 15.4: Countries with ERUDIT active nodes

European Union:		**Non-European Union:**	
Austria	2	Norway	
Belgium	2	Switzerland	1
Denmark	1	**Eastern Europe:**	1
Finland	4	Romania	
France	3	Russia	2
Germany	10	Slovakia	1
Greece	1	**Overseas:**	1
Italy	5	Brazil	
Sweden	3	USA	1
Spain	1		1
United Kingdom	5		
		Total Non-EU	
Total EU	**37**		**8**

Table 15.5: ERUDIT active nodes

Institution	Contact information
ABB Corporate Research, Finland	Kari Saarinen
Abo Akademi University, IAMSR, Finland	Christer Carlsson
AICA-Aassociacion para la investigacion y cooperacion industrial de Andalucia, Spain	Anibal Ollero
Ansaldo Ricerche S.r.l., Italy	Ricardo Parenti
CARITO S.r.l., Italy	Mario Fedrizzi
Centro Ricerche FIAT, Italy	A. Cannavacciuolo
Cerberus AG, Switzerland	Marc Thuillard
Coventry University, United Kingdom	Nigel Steele
Ecole Nationale Superieure des Telecommunications, France	Isabelle Bloch
ELITE-Foundation, Germany	H.-J. Zimmermann
Elsamprojekt A/S Denmark	Tommy Molbak
FLS Automation A/S, Denmark	J.-J. Ostergaard
FRAMENTEC-COGNITECH, France	Francois Arlabosse
Fuzzy Logik Systeme GmbH, Germany	Rudolf Felix
GEC Marconi Materials, Technology Hirst Division, U. K.	Robert Johnson
Helsinki University of Technology	Heikki N. Koivo
Horticulture Research International, U. K.	Graham King
Imperial College of Science and Technology	Abe Mamdani
Institut National des Sciences Appliquees - LAAS/CNRS France	Andre Titli
LAFORIA IBP-UPMC, France	B. Bouchon-Meunier
LUCAS Advanced Engineering Centre U. K.	Manzoor Arain
Metsa Serla Oy, Finland	Ossi Kokkonen
MIT GmbH, Germany	Richard Weber
Politecnico di Milano, Italy	Andrea Bonarini
SGS-Thomson Microelectronics, Italy	Antonino Milazzotto
Siemens Automotive S.A., France	Serge Boverie
SINTEF Instrumentation, Norway	Tom Kavli
Technical University of Denmark, Denmark	Jan Jantzen
Technische Hichschule Darmstadt, Germany	Rolf Iserman

Technische Universitat Carolo-Wilhemina zu Braunschweig, Germany	Rudolf Kruse
Thomson-CSF/CRL France	Michel Grabisch
UMIST - Control Systems Centre, University of Manchester, U. K.	Olaf Wolkenhauer
University of Granade, Spain	J.-L. Verdegay
Universitat Stuttgart, Germany	A. Jovanivic
Universite Liblre de Bruxelles, IRIDIA, Belgium	Philippe Smets
Universite Paul Sabatier, France	Henri Prade
University of Genoa, Italy	Francesco Masuli
University of Liege, Belgium	Marc Rubens
University of Naples, Frederico II, Italy	Giuseppe Zollo
University of Oulu, Finland	Esko Juuso
University of Southampton, Dept. of Electronics, U.K.	C. J. Harris

Long-term objectives of ERUDIT

o to establish an efficient communication structure between European scientists and practitioners interested in soft computing, in particular in **uncertainty modeling and fuzzy technology,**

o to disseminate research results of these methods to industry,

o to define a platform for future developments in the respective fields in industry and university

o to coordinate future research and training activities in this domain depending on the demand from the European industry,

o to promote technology transfer from universties to industry and more importantly, to transfer best practice among the industrial nodes of the network,

o to promote growth of this technology into new technological directions

ERUDIT Structure (committees and activities)

Figure 15.2 shows the overall structure of ERUDIT, its committees and activities:

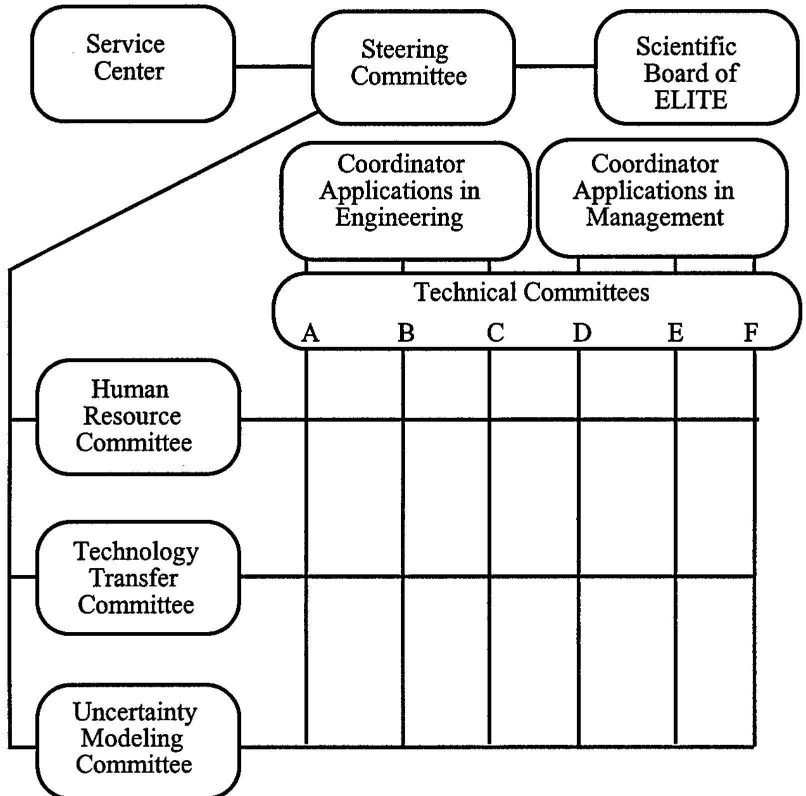

Figure 2: Overall organization of ERUDIT

The technical committees are grouped in two main fields:

o Applications in engineering including

A Control and monitoring

B Engineering design

C Environmental and Chemical Engineering

and

o Applications in management

D Active decision support

E Operational management

F Human factors

In addition there are three

Functional committees:

o Human Resource Committee

o Technology Transfer Committee

o Uncertainty Modeling Committee

Conclusion

Originating in Germany, in addition to activities in places such as Siemens, Volkswagen, GMD, and several universities, ERUDIT along with the EUFIT conferences and ELITE, indicate not only a strong interest in fuzzy logic based technology, but also a keen interest/desire to organize activities in this field, and to some extent control them, at European level (not only within Germany). To what extent this will be beneficial to the whole of the interested community remains to be seen.

16. IFSA'95 - The Sixth International Fuzzy Systems Association World Congress Sao Paolo, Brazil July 21-28, 1995

IFSA (the International Fuzzy Systems Association) has been created in 1985, when the first world congress on fuzzy systems has been held in Palma de Mallorca, Spain.

The IFSA Congress is held once every two (sometimes three years) in various locations in the world. In order to emphasize its international character and to stimulate interest in fuzzy logic based research and technology the IFSA Council has tried to organize the congress on a rotating basis on a different continent (table 16.1).

Table 16.1: IFSA World Congress locations

Year	Location
1985	Palma de Mallorca, Spain
1987	Tokyo, Japan
1989	Seattle, USA
1991	Brussels, Belgium
1993	Seoul, Korea
1995	Sao Paolo, Brazil
1996	Prague, Check Republic

The IFSA congress in Sao Paolo was not one of the largest ones (due in principal to the expense to travel to its location) however. it was an important congress, for reasons to be explained below.

Table 16.2 Participation by coutnry at IFSA'95

Country	No. of participants	Country	No. of participants
Austria	5	Hungary	1
Australia	1	Israel	1
Belgium	8	Italy	9
Brazil	136	Japan	37
Bulgaria	1	Korea	20
Canada	6	Mexico	1
China	2	Poland	1
Chile	1	Portugal	2
Croatia	2	Russia	4
Czech Republic	1	Slovenia	1
Denmark	3	Spain	20
Ecuador	1	Taiwan	7
Finland	2	Turkey	1
France	15	United Kingdom	6
Germany	16	United States	26
Hong Kong	1		

As it can be seen from Table 16.2 close to 50% (43.59%) of the participants came from Bražil alone. As one of the intended goals of hosting the congress in brazil was to stimulate interest in fuzzy systems research and technology, this high participation indicated at least an initial success in reaching this goal. At the same time, it was felt that in Brazil, a country with an energetic people there was already work in this technology, beyond of what was known outside Brazil.

Scientific Program

The scientific program has included more than 300 presentations (including plenary and semi-plenary presentations)., and a commemorative workshop dedicated to Lotfi Zadeh, with the occasion of 30 years anniversary since the publication of Zadeh's first paper on fuzzy sets. The workshop comprised six presentations, covering a wide range of problems to which fuzzy sets/fuzzy logic have proved beneficial.

Regular presentation sessions were organized in six parallel tracks:

- o Mathematical Foundations
- o Artificial Intelligence
- o Neural Networks and Hardware
- o Engineering
- o Information Systems
- o Health Sciences
- o Biology
- o Psychology
- o Fuzzy Systems

The proceedings of the conference contains 1400 pages (papers being limited four pages) which indicates the breadth of the program. Although not mentioned explicitly in the program the topic of soft computing, as integration of fuzzy sets/fuzzy logic, neural nets, genetic algorithms was very much in the focus of the conference.

Changes in IFSA organization

During the last few years changes in the character of IFSA have been discussed. Founded as a society, with individual membership only, IFSA responded to the need to provide a forum, and support for scientists interested in fuzzy systems. Since then a number of national societies have been created (e.g. NAFIPS - North American Fuzzy Information processing Society, SOFT - The Japanese Society for Fuzzy Theory, The Korean Fuzzy Mathematical Society, etc.). The largest national society is SOFT comprising approximately 2000 members.

At the IFSA Council meeting IFSA has been restructured as a Federation of national societies. It is not clear what will be the effects of this change in the future. In the near future it is clear that the balance of power in decision making about IFSA policy will shift heavily towards the Asian membership (in the

past, even though the Asian national societies were very large, the individual membership to IFSA from these countries was not much more than those from non Asian countries). This is due not only because of the large membership in the Asian national societies, but also because of the fact that Central and Eastern Europe countries have either very small national societies or none at all. This shift in the balance of power is not entirely unfair, as it must be emphasized that it is due too the engineering applications realized in Asia (first in Japan and more recently in Korea) that fuzzy technology has gained in interest everywhere else in the world.

Contact information

For further information about IFSA'95 the chairman of the steering committee can be contacted as follows:

Dr. Sandra Sandri

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17. The IJCAI'95 Workshop on Fuzzy Logic in Artificial Intelligence

The third Workshop on Fuzzy Logic in AI held in conjunction with an IJCAI meeting took place in Montreal, Canada, August 19, 21. The previous two workshops in 1991 and 1993 were held in Sydney, Australia and Chamberry, France respectively. The Montreal workshop was the first in this series approved for a two day period. Table 17.1 shows the workshop schedule for the two days. Attendance at the workshop was reasonable, given the fact that, in principle the workshop was more or less limited to those making presentations. However, as the organizer of these workshops I have usually opened them to anyone interested in attending the workshops.

Table 17.1 Schedule of the workshop (gray shaded text indicates no shows)

Saturday August 19 1995	Monday August 21, 1995
9:00-10:00 **Computing with words -- a bridge between human and machine intelligence.** Lotfi A. Zadeh, University of California Berkeley	8:30-10:00 **Automatic knowledge base tuning.** L. M. Sztandera **Extraction of knowledge from data using a fuzzy intelligent data browser** J. F. Baldwin, T. P. Martin **A model for learning fuzzy membership functions from examples.** F. Bergadano, V. Cutello
10:00-10:30 COFFEE BREAK	
10:30-12:30 **On Linguistic Variables and Fuzzy Sets for Hybrid Spatial Reasoning.** H. W. Guesgen **Fuzzy Logic as Interfacing Technique in Hybrid AI Systems.** Cristoff S. Herrmann **Reasoning about associative memory in a distributed system.** P. Camargo Silva **Integrating activities with neurofuzzy distributed systems.** A. B. S. Serapiao, A. F. Rocha	10:30-12:30 **A resemblance-based approach to analogical reasoning functions.** B. Bouchon-Meunier, L. Valverde **Case-based reasoning for numerical feature simulation using fuzzy feature representation** N. Hurley **An improved method for fuzzy inferencing using Zade implication operator.** S. Kundu **A generalized knowledge-based framework for be change.** P. Camargo Silva
12:30-2:00pm LUNCH	
2:00-3:30 pm **Application of nonmonotonic mechanism to fuzzy logic control.** R. R. Yager **Measurement-Theoretic Frameworks for Fuzzy Set Theory.** T. Bilgic, I. B. Turksen **Searching for the organizational memory with fuzzy logic.** A. Cannavacciuolo, G. Capaldo, A. Ventre	2:00-3:30 pm **Towards possibilistic decision theory.** D. Dubois, H. Prade **Hospital scheduling from a fuzzy logic programming perspective - Case study.** A. Gharakani W. Slany **Fuzzy Reasoning and applications for intelligent scheduling of robots.** E. Levner, L. Meyzin
3:30 - 4:00pm COFFEE BREAK	
4:00 - 5:30 pm **A Fuzzy System for Security Analysis.** V. Loia, S. Scandizzo **FLIP++: A fuzzy logic inference processor library.** M. Bonner, S, Mayer, A. Raggle, W. Slany **Using Fuzzy Logic for Approximate Reasoning in Expert System Design.** I. Popescu, E. Roventa	4:00 - 5:30 pm **Using fuzzy information in knowledge guided segmentation of brain tumors.** M. Clark, L. O. Hall, D. B. Goldof **FEDGE - Fuzzy edge detection by fuzzy categorization and classification of edges.** K. Ho, N. Onishi **Steps towards object cognition from images.** A. L. Ralescu, J. G. Shanahan.

In connection with IJCAI we note the following: IJCAI tends to be very exclusionary in general and rather anti fuzzy, in particular. For instance, in spite of the extensive work on fuzzy system, relevant to Artificial Intelligence, it was only at the last meeting that fuzzy systems were actually included as a possible topic for submissions. In the past, with the odd exception of one or two papers concerned with possibility theory (based on fuzzy logic) no papers using fuzzy logic were accepted for presentation at

this conference. In fact, there was no trivial matter to have the workshop accepted by the IJCAI workshop committee.

Papers presented at the previous two workshops were published in Springer Verlag Special Lectures in Artificial Intelligence (volume 833 and 847 respectively), and plans are under way to obtain the publishing permission for the this workshop.

For more information concerning these workshops (past of future) the contact information is:

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18. The Francophone Meetings on Fuzzy Logic and Applications
Paris, FRANCE
November 27-28, 1995

These meetings have as aim to bring together industry and university research on fuzzy logic. As the name suggests they are not restricted to French particiaoption but to the use of French language. It includes the French scientific community but also reserachers from North Africa, Spain, Italy and South America. The last of these meetings, organized in Paris, November 1995 proved to be the most suceesful yet. In spite of the emerging chaos due to the start of a general strike of transportation services throughout France (the meeting took place during the first two days of the strike, which lasted about three weeks) the meeting was well attended.

Forty eight presentations were made in three plenary and eleven regular sessions which covered the topics:

- o image processing
- o modeling
- o data aggregation and fusion
- o approximate reasoning
- o databases
- o learning
- o fuzzy control: theory and applications
- o clustering and classification
- o decision support systems
- o theoretical aspects of fuzzy logic

The non-academic participation accounted for approximately 50%. A special mention is due to the presentations from industry, as in many of these the fuzzy logic approach was selected only after isolation of problems which could not be solved satisfactorily by other methods. This drives home a very important and unique aspect of fuzzy logic, namely that it can be used as needed into existing problem solving techniques without necessitating a complete overhaul of the problem or approach. In fact, it is from this type of situations that most of the theory of fuzzy systems has developed, and in this sense, this theory is well anchored into reality.

Contact information

For further information regarding these meetings, the chair of the organizing committee can be contacted as follows:

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Appendix

Some International Events/Meetings on Fuzzy Logic related topics (bold titles indicate the more established conferences):

Title	place/date	contact information
Fuzzy Logic and the management of complexity -FLAMOC'96	Sydney, Australia January 15-18 1996	FLAMOC'96 fax: +61 47-76-16-16
3rd International Conference on Fuzzy Sets Theory and its applications-FSTA'96	Liptovsky Mikulas, Slovakia January 22-26 1996	Katedra Matematiky fax: +42 84-92-22-37 e-mail:dedera@valm.sk
4th IFSICC - International Fuzzy Systems and Intelligent Control Conference'96	Maui, Hawaii, USA April 8-11 1996	Patricia A. S. Ralston fax: +1 502 852-4713 e-mail:parals01@ulkyvm.louisville.edu
EFDAN'96 - European Workshop on Fuzzy Decision Analysis for Management	Dortmund, Germany May 21-22, 1996	Fuzzy Demonstrationszentrum Dortmund im ICD e.V. fax: +49 231 9700 929
ISSCI'96 - International Symposium on Soft Computing in Industry	Montpellier, France May 27-30 1996	Universidade Nova Lisboa fax: +351 1 2955641 e-mail:rr@fct.unl.pt
26th International Symposium in Multiple-valued logic	Santiago de Compostela, Spain May 29-31, 1996	fax: +34 81 530847 e-mail:ismvl-96@usc.es
NAFIPS'96 - Biennal Conference of the North American Fuzzy Information Processing	Berkeley, California, USA June 20-22, 1996	University of California, fax: +1 510 642-5775 e-mail: leem@cs.berkeley.edu
IPMU'96 Information Processing and Management of Uncertainty	Granada, Spain July 1-5, 1996	Universidad de Granada - IPMU'96 fax: +34 58243317 e-mail: ipmu96@robinson.ugr.es
EUFIT'96-4th European Congress on Intelligent Techniques and Soft Computing	Aachen, Germany September 2-5, 1996	ELITE Foundation fax: +49 2408 94582 e-mail:eufit@mitgmbh.de

FUZZ-IEEE'96 - The International IEEE Conference on Fuzzy Systems	New Orleans September 8-11, 1996	Frederick E. Petry e-mail: petry@cs.tulane.edu
FLINS'96 - 2nd International Workshop on Intelligent Systems and Soft Computing	Mol, Belgium September 25-27, 1996	Nuclear Research Center fax: +32 14321529 e-mail: flins@scken.be
International Panel Conference on Soft and Intelligent Computing	Budapest, Hungary September 30-October 3, 1996	Technical University of Budapest fax: +36 1 4633542
IIZUKA'96 - 4th International Conference on Soft Computing	Iizuka, Fukuoka, Japan September 30-October 5, 1996	Fuzzy Logic Systems Institute (FLSI) fax: +81 948243002 e-mail: iizuka96@flsi.cird.jp

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